Missouri Department of
Natural Resources
Water Protection Program

Total Maximum Daily Loads (TMDLs)

for

Stinson Creek
Callaway County, Missouri

Completed: February 5, 2010
Approved:

Total Maximum Daily Loads (TMDLs)
For Stinson Creek
Pollutant: Low Dissolved Oxygen and Organic Sediment


State map showing location of watershed

Name: Stinson Creek

Location: Callaway County near Fulton, Missouri

Hydrologic Unit Code: 10300102-270002

Water Body Identification: 0710

Missouri Stream Class: C[1]

Designated Beneficial Uses:
- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)
- Whole Body Contact Recreation – Category B.

Location of Impaired Segment: From Mouth to Section 16, T47N, R9W

Length of Impaired Segment: 9 miles

Location of Impairment within Segment: NE ¼ Section 21, T47N, R9W to NE ¼ Section 21, T47N, R9W

Length of Impairment within Segment: 0.1 miles

Use that is impaired: Protection of Warm Water Aquatic Life

Pollutants:
- Low Dissolved Oxygen
- Organic Sediment

TMDL Priority Ranking: High

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[1] Class C streams may cease to flow in dry periods but maintain permanent pools which support aquatic life. See the Missouri Water Quality Standards at 10 Code of State Regulations 20-7.031(1)(F). The water quality standards can be found at the following uniform resource locator :http://www.sos.mo.gov/adrules/csr/current/10csr/10csr.asp#10-20

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1 Introduction

This Stinson Creek Total Maximum Daily Load, or TMDL, is being established in accordance with Section 303(d) of the Clean Water Act. This water quality limited segment near Fulton in Callaway County, Missouri is included on the Environmental Protection Agency, or EPA, approved Missouri 2008 303(d) List.

The purpose of a TMDL is to determine the pollutant loading a water body can assimilate without exceeding the water quality standards for that pollutant. Water quality standards are benchmarks used to assess the quality of rivers and lakes. The TMDL also establishes the pollutant load allocation necessary to meet the Missouri water quality standards established for each water body based on the relationship between pollutant sources and instream water quality conditions. The TMDL consists of a wasteload allocation, a load allocation and margin of safety. The wasteload allocation is the portion of the allowable load that is allocated to point sources. The load allocation is the portion of the total pollutant load that is allocated to nonpoint sources. The margin of safety accounts for the uncertainty associated with the model assumptions and data inadequacies.

Section 2 of this report provides background information on the Stinson Creek watershed and Section 3 describes potential sources of concern. Section 4 presents the applicable water quality standards, Section 5 describes the water quality problems, and Section 6 describes the modeling that was done to support the TMDL. Sections 7 to 11 present the required TMDL elements (loading capacity, wasteload allocation, load allocation and margin of safety) and Sections 12 to 15 summarize the follow-up monitoring plan, implementation activities, reasonable assurances, and public participation. A summary of the administrative record is presented in Section 16. Appendix A displays the available water quality data; Appendix B describes development of suspended solids targets using reference load duration curves; and Appendix B provides more information on the modeling.

2 Background

This section of the report provides information on Stinson Creek and its watershed.

2.1 The Setting

Stinson Creek originates northwest of Fulton, Missouri, in Callaway County, and flows southeast for 25 miles through Fulton to join Auxvasse Creek (Figure 1). The Auxvasse is a direct tributary to the lower Missouri River, which forms the southern boundary of the county.

Stinson Creek was first listed on Missouri's Section 303(d) List of impaired waters for biochemical oxygen demand and volatile suspended solids in 1994. Biochemical oxygen demand is the measure of oxygen used by microorganisms to decompose organic matter. Volatile suspended sediments are those sediments that can be removed from the water by filtration and are lost on ignition (heating to 550 degrees Celsius) and approximate the amount of organic matter contained in a water sample.

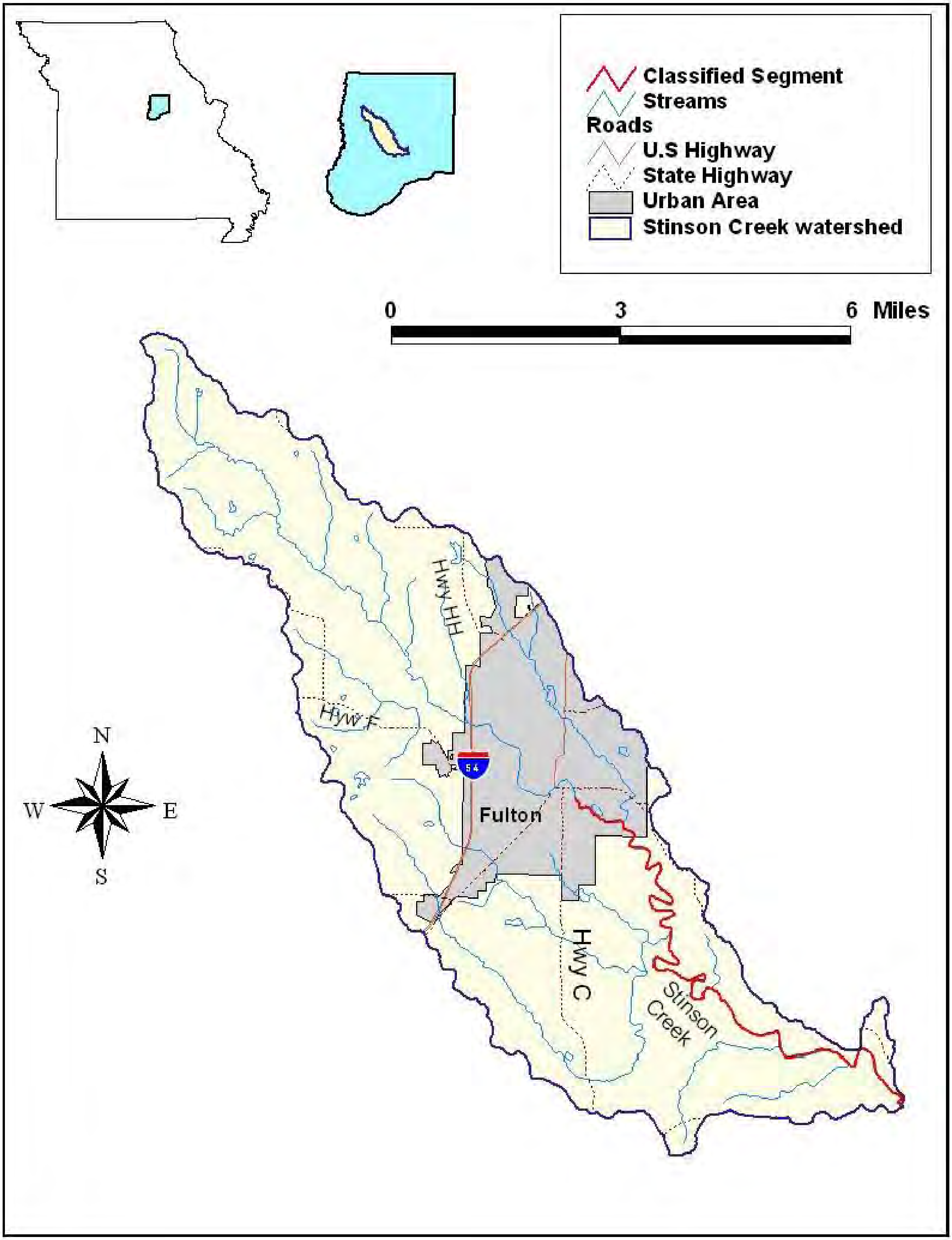

Figure 1. Location of Stinson Creek watershed, Callaway County.

Missouri changed the listed causes of impairment from biochemical oxygen demand to dissolved oxygen, and from volatile suspended sediments to organic sediment, on its 2004/2006 303(d) List to provide a more understandable list to the general public. The causes of the impairments, and the data used to identify them, have not changed and these impairments remain on the 2008 303(d) List of impaired waters.

2.2 Population

The population of the Stinson Creek watershed is not directly available. However, the Census reports that the 2007 population for Fulton is approximately 12,000 (Census Bureau, 2008). Additionally, the rural population of the watershed can be roughly estimated based on the proportion of the watershed that is located in Callaway County. Callaway County covers an area of 838 square miles and has a population of approximately 41,000. Since the rural population in Callaway County is approximately 29,000 (total county population minus urban area population) and the rural area of the Stinson Creek watershed is approximately 43 square miles, the rural population of the watershed is estimated as 1,488 persons (43 square miles divided by 838 square miles multiplied by 29,000 persons).

2.3 Geology and Soils

The Stinson Creek watershed ranges in elevation from 520 to 921 feet, with slopes ranging from gentle in the stream bottoms and some upland areas, to moderate to severe throughout much of the rest of the watershed. This area has been glaciated and, geologically, the entire basin is within the Pennsylvanian system. The Pennsylvanian groups in this area – the Marmaton and Cherokee – are characterized by cyclic deposits of shale, sandstone, clay and coal, with limestone in some areas.

Roughly the bottom two-thirds of the basin is known as the River Hills ecoregion, which is characterized by smooth to moderately dissected forested stream-side slopes and bluffs, and some loess-covered hills. This is the transition zone between the loess- and till-covered plains to the north, and the rockier and more deeply dissected Ozark Highlands to the south. The northwestern-most third of the Stinson Creek basin is the Claypan Prairie ecoregion, characterized by well-developed claypan soils on glacial till. This area is more level to gently rolling than the River Hills region, with little bedrock exposure (Chapman et al., 2002).

The Soil Survey Geographic database developed by the Natural Resources Conservation Service shows that greater than 92 percent of the soils in the Stinson Creek watershed are characterized as having slow or very slow infiltration rates, and roughly 89 percent of the land area is considered highly erodible or potentially highly erodible (USDA, 2007). Soil groups are represented predominantly by Keswick loams, Mexico silt loams, and the Goss-Gasconade-Rock outcrop complex. This latter complex is found on moderate to very steep upland slopes, and is characterized as excessively well drained, with a high potential for rapid surface runoff. Organic matter is low to moderately low, with the predominant natural vegetation an oak-hickory mixed hardwood complex. Mexico silt loams found here are deep, poorly drained soils located in the more gently sloping upland areas. They are used for row crops, hay, or pasture, and the potential for surface runoff is moderate in cultivated areas. Organic content is moderate with erosion being a problem during seedbed preparation. The largest soil complex in the watershed is the deep, moderately sloped, moderately well drained Keswick loam. Organic matter content is moderately low, with erosion also a problem. The area is suited for row crops, pasture, and woodland (USDA, 1992).

The average annual precipitation within the Stinson Creek watershed is nearly 39 inches, with the majority of this falling during the freeze-free months. Maximum rainfall generally occurs in the spring and early summer, with a period of minimum rainfall from mid-summer through fall. Slow infiltration rates and a moderate to severe potential for runoff – along with low to moderate soil water holding capacities – serve to indicate that stream flow is primarily sustained by surface precipitation and runoff, and that stream base flow is not well sustained during dry periods. This supports field observations during low-flow studies that document parts of the upper reaches of Stinson Creek in late summer as being characterized by isolated pools with little or no stream flow connecting them.

2.4 Land Use

Historically, the Stinson Creek watershed was dominated by tall grass prairies and oak and hickory forests in uplands and along stream corridors. Today, land use consists of 44 percent grassland (which can include pastures), 28 percent forest, 14 percent cropland, and 10 percent urban. The land use of the watershed is shown in Figure 2 and summarized in Table 1 (MORAP, 2005).

Table 1. Land use in the Stinson Creek watershed.

Land Use Type	Watershed Area		Percent
	Acres	Square Miles	
Urban	2938.05	4.59	9.80
Cropland	4204.58	6.57	14.03
Grassland	13210.87	20.64	44.07
Forest	8487.67	13.26	28.32
Herbaceous	121.87	0.19	0.41
Wetland	307.57	0.48	1.02
Open Water	701.21	1.10	2.35
Total	29971.82	46.83	100.00

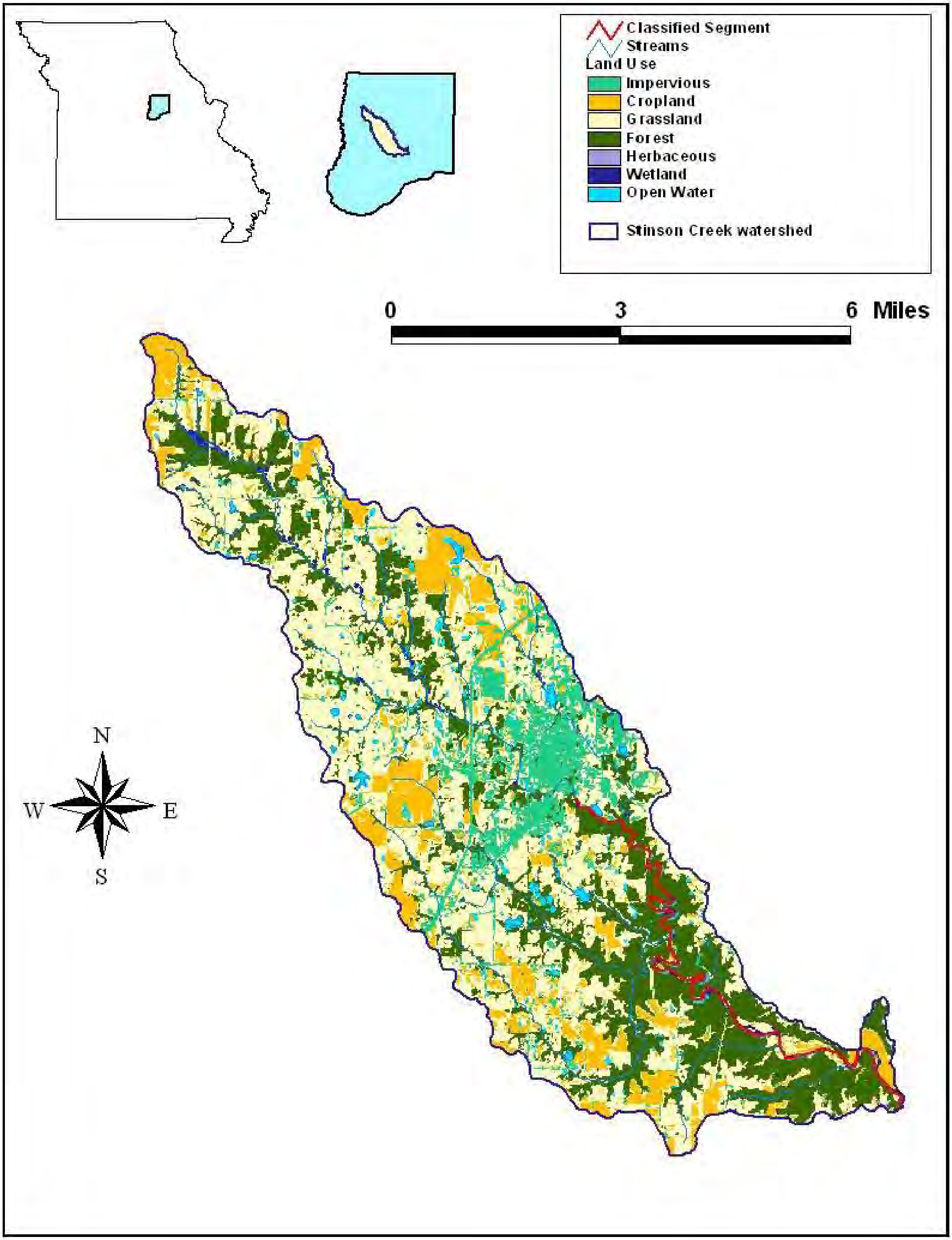

Figure 2. Land use in the Stinson Creek watershed.

2.5 Defining the Problem

A TMDL is needed for Stinson Creek because it is not meeting water quality standards for dissolved oxygen and organic sediment. Low dissolved oxygen is a problem because concentrations have been measured at less than the water quality criterion of 5 mg/L. Organic sediment is a problem based on observed violations of the narrative criteria described in Section 4.2.2. Organic sediment can also contribute to low dissolved oxygen conditions.

Water from Stinson Creek was sampled and analyzed by the Department in August 2001, August 2002, and August 2007. The data produced by the Department are of sufficient quality to evaluate compliance with water quality standards and to support TMDL development. The dissolved oxygen results for the seven Department surveys are summarized in Table 2 and indicate that a minimum of four percent of the dissolved oxygen samples from each survey were less than 5 mg/L. All of the data from these surveys is presented in Appendix A.

Table 2. Summary of MoDNR dissolved oxygen data for Stinson Creek.

Survey	Number of Samples	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Percentage of Samples < 5 mg/L
October 1991	3	2.7	4.4	6.6	67%
September 1993	18	4.8	8.0	12.3	6%
September 1999	4	3.1	5.2	6.0	25%
October 1999	5	4.7	6.9	8.1	20%
August 2001	6	4.4	7.4	12.8	50%
August 2002	6	3.9	6.1	12.9	67%
August 2007	4	1.8	2.0	2.1	100%

Note: The data represent dissolved oxygen concentrations both upstream and downstream of the Fulton Wastewater Treatment Plant

As discussed in Section 4, the low dissolved oxygen problem could be due to one or more of the following:

- Excessive loads of decaying organic solids, as measured by biochemical oxygen demand.
- Too much algae in the stream as a result of excessive phosphorus or nitrogen loading.
- High consumption of oxygen from decaying matter on the streambed.
- Physical factors associated with low reaeration rates.

Because physical factors could be contributing to the dissolved oxygen impairment, an additional low-flow study of the upper Stinson Creek watershed was conducted in August of 2007 (MDNR 2007). Such physical factors include a system with naturally low flows due to a lack of groundwater inputs or a lack of riffles that reduce dissolved oxygen re-aeration rates. This study indicated that, due to an absence of stream flow, much of the upper portion of the watershed was hydrologically disconnected from the lower watershed during dry periods. The study concluded that the wastewater treatment facilities in the upper portion of the watershed had no observable negative impact on water quality at the time of the study (during low flow), nor did upstream water quality have any effect upon water quality downstream of the Fulton Wastewater Treatment Plant under these conditions. The low dissolved oxygen concentrations were primarily related to physical factors associated with low flow conditions.

3 Source Inventory

This section summarizes the available information on significant sources of nutrients, oxygen-consuming substances, and organic sediment in the Stinson Creek watershed. Point (or regulated) sources are presented first, followed by nonpoint (or unregulated) sources.

3.1 Point Sources

The term "point source" refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. Point sources are regulated through the federal National Pollutant Discharge Elimination System, which is administered at the state level through the Missouri State Operating Permit system. The permitted facilities in the Stinson Creek watershed are listed in Table 3 and facilities with available coordinates are displayed in Figure 3. There are a total of 33 facilities: 13 with site-specific permits, 4 general permits, and 16 with storm water permits. Storm water permits are issued to activities that discharge only in response to precipitation events. One of the storm water permits is a municipal separate storm sewer system for the city of Fulton. General permits (as opposed to site-specific permits) are issued to activities that are similar enough to be covered by a single set of requirements.

The municipal separate storm sewer system permit for the city of Fulton is based on Fulton having a 2000 census population of 10,000 or more, and covers the entire area incorporated by the city. The total area included within the Fulton municipal separate storm sewer system permit is 11.3 square miles. The portion of this permit within the Stinson Creek watershed is 9.6 square miles, and includes discharge from 25 out of 33 of the permitted storm water outfalls.

The Fulton Wastewater Treatment Plant is the largest permitted facility in the watershed with a design flow that comprises more than 94 percent of the total of all facilities shown in Table 3[2]. The Fulton Wastewater Treatment Plant merits special attention because of its size and also because it is located just upstream of the impaired segment. The facility was built in 1987, and consists of an oxidation ditch, sludge holding tanks, clarifiers, and aerobic sludge digesters. It has a design flow of 2.93 million gallons per day, although it is currently operating at a flow of 1.7 million gallons per day. The sludge is land applied, and in 1998 the city installed a new vacuum-assisted biosolids dewatering system that dramatically reduced the volume of dewatered material. The sludge is provided to a variety of farmers throughout the county but most of it is applied to the southeast of Fulton (Greg Hayes, city of Fulton, personal communication, March 10, 2009).

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[2] The design flow shown in Table 2 for the Harbison-Walker Refractor permit is for storm water discharges only and was not included in the referenced calculation.

Like all wastewater treatment plants in Missouri, the Fulton Wastewater Treatment Plant must meet the requirements of a discharge permit issued by the Missouri Department of Natural Resources (the Department). This permit contains discharge limits that the treatment plant must meet to be protective of instream water quality standards. The current discharge permit expires August 11, 2010. The permit was most recently reissued in August of 2005 with revised biochemical oxygen demand and total suspended solid effluent limitations at the facility's Outfall #002. Weekly average biochemical oxygen demand was lowered from 65 to 45 mg/L, and weekly average total suspended solids was lowered from 120 to 45 mg/L. Biochemical oxygen demand and total suspended solids limits for treated Outfall #001 remained unchanged, both with weekly averages of 45 mg/L and monthly averages of 30 mg/L. At the direction of EPA, when the operating permit for the Fulton WWTP is next renewed, a condition will be placed in the permit requiring the facility to eliminate Outfall #002 and redirect overflow from the lagoon into the mechanical treatment plant.

A mixing zone currently applies to this permit, extending approximately 1000 feet downstream from outfall 001 to just above the Stinson Creek confluence with Smith Branch. However, as a result of rule changes incorporated into the Missouri Code of State Regulations in November 2005, mixing zones are no longer allowed in low-flow streams with 7-day Q_{10} low flows of less than 0.1 cfs, such as Stinson Creek.[3] It is expected that the permit will be revised to comply with the new standards the next time the permit is opened for reissuance. Modeling of waste load allocations does not incorporate a mixing zone.

By law, the term "point source" also includes concentrated animal feeding operations (which are places where animals are confined and fed). There is one concentrated animal feeding operation, Echo-L-Holsteins, located in the Stinson Creek watershed. As noted in Table 3, this facility is regulated under a general permit

Since critical conditions for low dissolved oxygen and organic sediment occur during periods of low stream flow, it is unlikely that storm water discharge from facilities with storm water permits are a significant contributor to the low dissolved oxygen problem. It is also unlikely the general permits for land application of wastewater will contribute to the dissolved oxygen problem because these permits are no-discharge and contain restrictions designed to minimize the impact of land application to surface waters. Similarly, concentrated animal feeding operations are no-discharge except during storms exceeding the design storm event, and so are not likely to impact streams during critical periods of low flow. The other types of general permits within the Stinson Creek watershed do allow both storm and non-storm water discharge. However, these facilities are also required to adhere to operating conditions with the permits designed to minimize their impacts to surface waters.

Illicit straight pipe discharges of household waste are also potential point sources in rural areas. These are discharges straight into streams or land areas and are different than illicitly connected sewers. There is no specific information on the number of illicit straight pipe discharges of household waste in the Stinson Creek watershed.

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[3] Missouri Water Quality Standards at 10 Code of State Regulations 20-7.031(4)(A)4B(I)(a). 7-day Q_{10} low flows are defined as the lowest average flow for 7 consecutive days that has a probable recurrence interval of once in 10 years.

Table 3. Permitted facilities in the Stinson Creek watershed.

Facility ID	Facility Name	Receiving Stream	Design Flow (MGD)	Permit Expiration Date
MO0003018	Harbison-Walker Refractor	Tributary Stinson Creek	0.874	2010
MO0049590	Red Maples Mobile Home Community	Youngs Creek	0.038	2008
MO0085936	Tower Mobile Home Park	Tributary Stinson Creek	0.022	2013
MO0093742	Christopher Subdivision #2	Tributary Stinson Creek	0.007	2012
MO0093751	Green Meadows Subdivision	Tributary Stinson Creek	0.019	2008
MO0093882	Mertens Convenience Store	Tributary Youngs Creek	0.012	2013
MO0102148	Country Livin' Subdivision	Tributary Youngs Creek	0.005	2008
MO0103331	Fulton WWTP	Stinson Creek	2.930	2010
MO0124290	Callaway Christian Church	Youngs Creek	0.001	2012
MO0125571	Callaway Raceway	Tributary Youngs Creek	0.002	2011
MO0128104	Red Creek Estates	Tributary Stinson Creek	0.007	2009
MO0129020	Stonehaven Estates	Tributary Youngs Creek	0.023	2009
MO0132713	Master Key Homeplace Subdivision	Tributary Youngs Creek	0.020	2012
MOG010552	Echo-L Holsteins	Smith Branch	General Permit	2011
MOG490549	A.P. Green Refractories	Tributary North Fork Smith Branch	General Permit	2011
MOG490763	Mo-Con, Inc	Tributary Stinson Creek	General Permit	2011
MOG822156	Backer Potato Chip Co.	Unnamed Tributary Smith Branch	General Permit	2011
MOR040061	Fulton Small MS4	Tributary Young's Creek	Storm water Permit	2013
MOR10A195	Southwind Estates Plat 4	Tributary Stinson Creek	Storm water Permit	2012
MOR10A265	Walgreen's Retail Center	Tributary Smith Branch	Storm water Permit	2012
MOR10A344	Helm Subdivision	Tributary Smith Branch	Storm water Permit	2012
MOR10A408	Central Missouri Energy	Tributary Stinson Creek	Storm water Permit	2012
MOR10A989	Westminster College	Tributary Stinson	Storm water	2012

Facility ID	Facility Name	Receiving Stream	Design Flow (MGD)	Permit Expiration Date
	Residence Hall	Creek	Permit	
MOR10B037	Junior Lake (William Woods University)	Smith Branch	Storm water Permit	2012
MOR10B740	Callaway Electric Industries	Tributary Youngs Creek	Storm water Permit	2012
MOR10B749	Stonehaven Estates Subdivision	Tributary Big Hollow	Storm water Permit	2012
MOR80H008	Kingdom Projects Inc	Tributary Dunlop Creek	Storm water Permit	2009
MOR102553	Tanglewood Estates	Tributary Stinson Creek	Storm water Permit	2012
MOR103423	Tanglewood Estates #3,4,5	Tributary Richland Creek	Storm water Permit	2012
MOR104115	Tanglewood Business Park	Tributary Smith Branch	Storm water Permit	2012
MOR105239	Tanglewood Fastlane	Tributary To Stinson Creek	Storm water Permit	2012
MOR107435	Fulton Commons	Unnamed Tributary Big Hollow	Storm water Permit	2012
MOR109Q64	Westminster College Dining Hall	Stinson Creek	Storm water Permit	2012

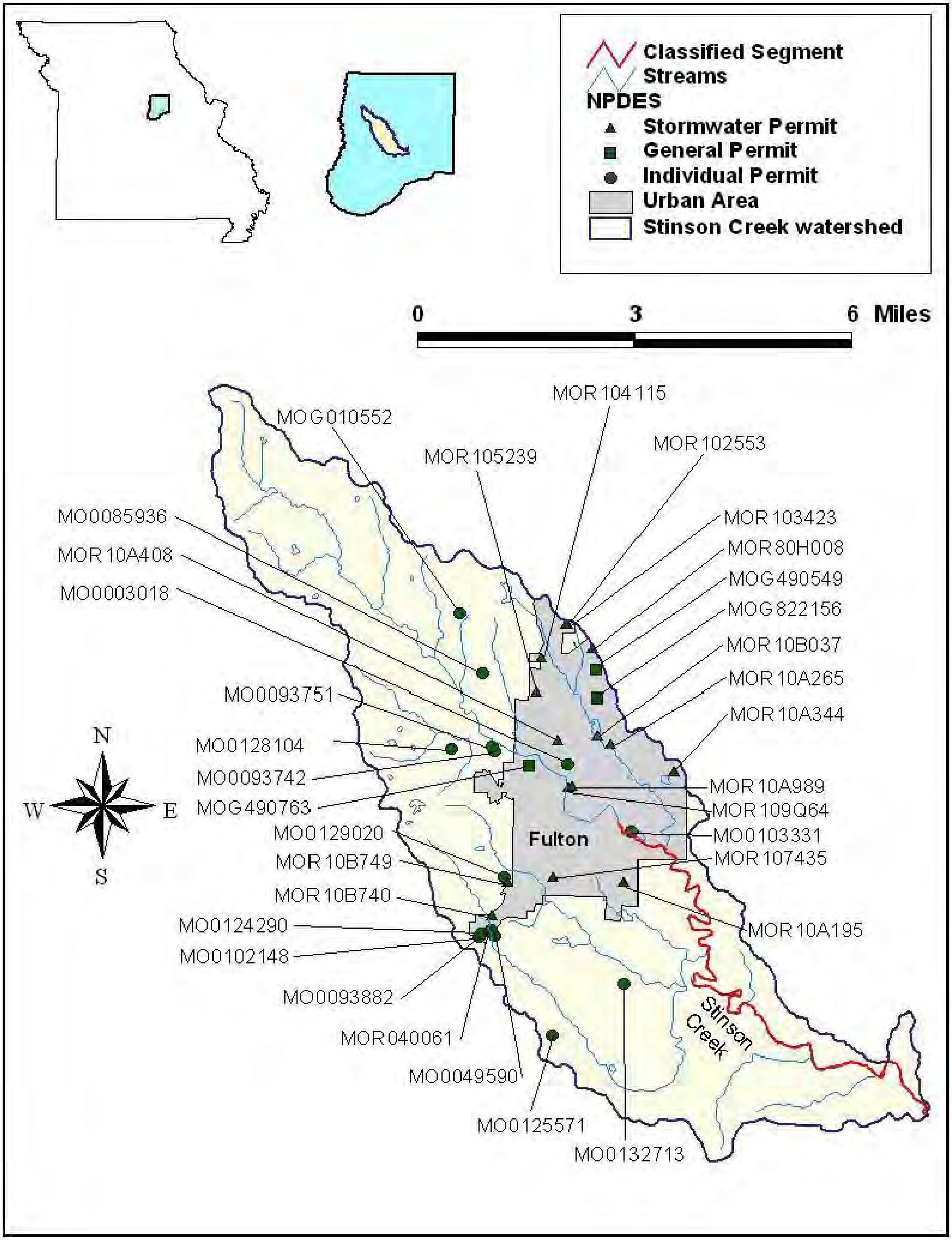

Figure 3. Location of permitted facilities in the Stinson Creek watershed.

3.2 Nonpoint Sources

Nonpoint sources include all other categories not classified as point sources. Potential nonpoint sources in the Stinson Creek watershed include runoff from agricultural areas, runoff from urban areas, onsite wastewater treatment systems, and various sources associated with riparian habitat conditions. Each of these is discussed further in the following sections.

3.2.1 Runoff from Agricultural Areas

Lands used for agricultural purposes can be a source of nutrients, organic sediment and oxygen-consuming substances. Accumulation of nitrogen and phosphorus on cropland occurs from decomposition of residual crop material, fertilization with chemical and manure fertilizers, atmospheric deposition, wildlife excreta and irrigation water. The land use data indicates that there are 4,204 cropland acres in the watershed (MORAP, 2005). This represents approximately 14 percent of the entire watershed area. Additionally, nearly 2 percent of the riparian corridor is classified as cropland (see Table 4)

Countywide data from the National Agricultural Statistics Service (USDA, 2002) were combined with the land cover data of the Stinson Creek watershed to estimate that there are approximately 3,400 cattle in the watershed[4]. The cattle are located on the approximately 13,210 acres of grassland/pastureland identified in the land use database. Runoff from feeding operations and pasture areas can be potential sources of nutrients, sediment and oxygen-consuming substances. For example, animals grazing in pasture areas deposit manure directly upon the land surface and, even though a pasture may be relatively large and animal densities low, the manure will often be concentrated near the feeding and watering areas in the field. These areas can quickly become barren of plant cover, increasing the possibility of erosion and contaminated runoff during a storm event. Based on previous TMDL projects by Tetra Tech and others, the density of cattle in the Stinson Creek watershed (74 cattle per square mile) suggests they are a potentially significant source of pollutants (OEPA, 2007; Tetra Tech, 2009). The National Agricultural Statistics Service also reports that there were 49,501 hogs and pigs, 676 sheep and lambs and 84 poultry broilers in Callaway County in 2002. No data are available to estimate the number of these other livestock that might be located in the Stinson Creek watershed.

3.2.2 Runoff from Urban Areas

Storm water runoff from urban areas can also be a significant source of nutrients, organic sediment and oxygen-consuming substances. Lawn fertilization can lead to high nutrient loads and pet wastes can contribute both nutrient loads and oxygen-consuming substances. For example, phosphorus loads from residential areas can be comparable to or higher than loading rates from agricultural areas (Reckhow et al., 1980; Athayde et al., 1983). Leaking or illicitly

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[4] According to the National Agricultural Statistics Service there are approximately 49,500 head of cattle in Callaway County (http://www.nass.usda.gov/). According to the 2005 Missouri Resource Assessment Program there are 300 square miles of grassland in Callaway County. These two values result in a cattle density of approximately 165 cattle per square mile of grasslands. This density was multiplied by the number of square miles of grassland in the Stinson Creek watershed to estimate the number of cattle in the watershed.

connected sewers can also be a very significant source of pollutant loads within urban areas. Storm runoff from urban areas such as parking lots and buildings are also warmer than runoff from grassy and woodland areas, which can lead to higher temperatures that lower the dissolved oxygen saturation capacity of the stream. Excessive discharge of suspended solids, including organic sediment, from urban areas can also lead to streambed siltation problems.

Approximately 4.6 square miles, or 9.8 percent, of the Stinson Creek watershed is classified as urban based on an assessment of impervious land cover. Fulton's municipal separate storm sewer system permit (which can include both pervious and impervious land surfaces) accounts for 9.6 square miles within the watershed. Since Fulton is the only incorporated urban area in the Stinson Creek watershed, most, if not all, urban runoff is likely collected and discharged through the Fulton municipal separate storm sewer system. As a result, nonpoint source urban storm water runoff is not likely a significant source of substances or conditions contributing to low dissolved oxygen and organic sediment in Stinson Creek.

3.2.3 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems (e.g., septic systems) that are properly designed and maintained should not serve as a source of contamination to surface waters. However, onsite systems do fail for a variety of reasons. When these septic systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration) there can be adverse effects to surface waters (Horsely and Witten, 1996). Failing septic systems are sources of nutrients that can reach nearby streams through both surface runoff and ground water flows.

The exact number of onsite wastewater systems in Stinson Creek watershed is unknown. However, as discussed in Section 2.2, the estimated rural population of the Stinson Creek watershed is approximately 1,488 persons. Based on this population and an average density of 2.5 persons per household, there may be approximately 595 systems in the watershed. The Callaway County Health Department, which has regulatory authority over onsite systems, does not suspect that failing onsite wastewater systems are a significant problem along Stinson Creek because there are few houses located adjacent to the creek (Kent Wood, Callaway County Health Department, personal communication, March 9, 2009). However, EPA reports that the statewide failure rate of onsite wastewater systems in Missouri is 30 to 50 percent (EPA, 2002).

3.2.4 Riparian Habitat Conditions

Riparian habitat[5] conditions can also have a strong influence on instream dissolved oxygen and organic sediment. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the detention, removal, and assimilation of nutrients and sediment before they reach surface water. Therefore a stream with good riparian habitat is better able to moderate the impacts of high nutrient and sediment loads than a stream with poor habitat. Wooded riparian corridors can also provide shading that reduces stream temperatures, which can increase the dissolved oxygen saturation capacity of the stream.

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[5] A riparian corridor (or zone or area) is the linear strip of land running adjacent to a stream bank.

Riparian areas can also be sources of natural background material that could possibly contribute to the organic sediment and low dissolved oxygen problems. For example, leaf fall from vegetation near the water's edge, aquatic plants, and drainage from organically rich areas like swamps and bogs are all natural sources of materials that consume oxygen.

As indicated in Table 4, more than half of the land in the Stinson Creek riparian corridor is classified as forest or wetland. Another 10 percent of the riparian corridor is classified as impervious and urban areas, which provide limited habitat and shading and can be associated with high nutrient loads associated with lawn fertilization and pet waste. Efforts to improve riparian habitat conditions should therefore be an important component of the implementation of the TMDL.

Table 4. Percentage land use within riparian corridor (30-meter) (MORAP, 2005).

Land Use/Land Cover	Percentage
Urban	9.79
Cropland	2.35
Grassland	8.64
Forest	44.27
Wetland	16.33
Open Water	18.62

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4 Applicable Water Quality Standards and Numeric Water Quality Targets

The purpose of developing a TMDL is to identify the pollutant loading that a water body can receive and still achieve water quality standards. Water quality standards are therefore central to the TMDL development process. Under the federal Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters (U.S Code Title 33, Chapter 26, Subchapter III (U.S. Code, 2009)). Water quality standards consist of three components: designated beneficial uses, water quality criteria to protect those uses, and an antidegradation policy.

4.1 Designated Beneficial Uses

The designated beneficial uses of Stinson Creek, WBID 0710, are:

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)
- Whole Body Contact Recreation – Category B.

The use that is impaired is Protection of Warm Water Aquatic Life. The designated beneficial uses and stream classifications for Missouri may be found in the Water Quality Standards at 10 CSR 20-7.031(1)(C), (1)(F) and Table H (Missouri Secretary of State, 2008).

4.2 Numeric Criteria

Missouri's criteria that relate to dissolved oxygen and organic sediment are presented in the following sections. The sections also provide brief descriptions of why dissolved oxygen and organic sediment are important to water quality, how they are measured, and how they are related to other water quality parameters.

4.2.1 Low Dissolved Oxygen

Dissolved oxygen is one of the most critical characteristics of our surface waters because fish, mussels, macroinvertebrates, and most other aquatic life utilize dissolved oxygen in the water to survive. The water quality criterion for dissolved oxygen for all Missouri streams, except cold water fisheries, is a daily minimum of 5 mg/L (10 CSR 20-7.031 Table A (Missouri Secretary of State, 2008)).

Dissolved oxygen in streams is affected by several factors including water temperature, the amount of decaying matter in the stream, turbulence at the air-water interface, and the amount of photosynthesis occurring in plants within the stream. Decaying matter can come from wastewater effluent as well as agricultural and urban runoff and is typically measured instream as biochemical oxygen demand.

Nitrogen and phosphorus can also contribute to dissolved oxygen problems because they can accelerate algae growth in streams. Algae growth in streams is most frequently assessed based on the amount of chlorophyll *a* in the water. The algae consume dissolved oxygen during respiration at night and have the potential to remove large amounts of dissolved oxygen from the stream. The breakdown of dead, decaying algae also removes oxygen from water. The dissolved oxygen, biochemical oxygen demand, nitrogen, and phosphorus data for Stinson Creek are summarized in Section 5.

4.2.2 Organic Sediment

Stinson Creek is also listed for organic sediment, but there are no specific criteria for this pollutant. The general, or narrative, criteria that apply may be found in the general criteria section of the water quality standards at 10 CSR 20-7.031(3)(A) and (C) (Missouri Secretary of State, 2008). Here it states:

- Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses.
- Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses.

Wastewater treatment plants may discharge high levels of organic sediment (as opposed to sand and silt). Organic sediment can settle onto the bottom of a stream and smother natural substrates (materials in the streambed), aquatic invertebrate animals (like mayfly larvae and crayfish) and fish eggs. Also, high amounts of organic sediment contribute to sludge on the stream bottom, which has an offensive odor in addition to being unsightly.

Through previous experience the Department has found that the treatment technology required to reduce biochemical oxygen demand should result in corresponding reductions in organic sediment. Organic sediment is one component of total suspended solids. Section 8 of this report discusses the development of wasteload allocations that will be used in setting new limits for biochemical oxygen demand and total suspended solids for the Fulton Wastewater Treatment Plant.

4.3 Antidegradation Policy

Missouri's water quality standards include EPA's "three-tiered" approach to antidegradation, which may be found at 10 CSR 20-7.031(2) (Missouri Secretary of State, 2008).

> Tier 1 – Protects existing uses and a level of water quality necessary to maintain and protect those uses. Tier 1 provides the absolute floor of water quality for all waters of the United States. Existing instream water uses are those uses that were attained on or after November 28, 1975, the date of EPA's first Water Quality Standards Regulation.
>
> Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an anti-degradation review consisting of: (1) a finding that it is necessary to accommodate important economical or social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing or designated uses.
>
> Tier 3 – Protects the quality of outstanding national and state resource waters, such as waters of national and state parks, wildlife refuges, and exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality.

Waters in which a pollutant is at, near or exceeds the water quality criteria are considered in Tier 1 status for that pollutant. Therefore, the antidegradation goal for Stinson Creek is to restore the stream's dissolved oxygen level to the water quality standards.

5 TMDL Development

5.1 Data Collection

To more fully understand the cause of the low dissolved oxygen problem, additional data from Stinson Creek were sampled and analyzed in 2008 by Tetra Tech, Inc. under contract with EPA. These data are also of sufficient quality to evaluate compliance with water quality standards and to support TMDL development because they were collected in accordance with required quality assurance procedures and Department sampling protocols (Tetra Tech, 2008a; 2008b; MDNR, 2005).

The location of the sampling sites in May and September 2008 are provided in Figure 4 and the data are summarized in Table 5 and Table 6. Data loggers were deployed at two of the locations (ST-2 and ST-4) during both surveys and the 15 minute dissolved oxygen data from those are presented in Figure 5 and Figure 6.

There are several issues worth noting from a review of the available Stinson Creek data:

- None of the individual grab samples had dissolved oxygen concentrations below 5 mg/L during the May or September 2008 field sampling. However, the continuous dissolved oxygen data from May showed several periods where dissolved oxygen fell below 5 mg/L at ST-4, which is 0.1 miles downstream of the Fulton Wastewater Treatment Plant.
- Total suspended solids were elevated downstream of the wastewater treatment plant during the May 2008 sampling event, which took place during a period of low flow.
- Chlorophyll *a* was extremely high (251 to 304 µg/L) in Stinson Creek downstream of the Fulton Wastewater Treatment Plant during the May sampling. Chlorophyll *a* increased from seven µg/L upstream of the wastewater treatment plant to 304 µg/L downstream of the wastewater treatment plant. Values were also elevated, but not quite as high, during the September sampling event.
- Total phosphorus concentrations in the effluent of the wastewater treatment plant were 3.1 mg/L in May 2008 and 0.94 mg/L in September 2008. This caused instream phosphorus concentrations to be elevated for several miles downstream.
- The nitrite + nitrate concentration in the effluent of the wastewater treatment plant in May 2008 was 17 mg/L. This caused instream nitrite+nitrate concentrations to be elevated for several miles downstream. Effluent nitrite+nitrate in September 2008 was 2.4 mg/L.

These data suggest that high nutrient loads from the Fulton Wastewater Treatment Plant are contributing to excessive algal growths downstream. The excessive algal growths, in turn, may be causing low dissolved oxygen to occur late at night when the algae are consuming but not producing dissolved oxygen. Large amounts of algae may also be contributing to organic sediment and low dissolved oxygen when they decay. Low flows associated with the natural hydrology of the stream might also be contributing to the problem, but are unlikely to be the sole cause of the impairment.

The relatively high concentrations of total suspended solids measured downstream of the wastewater treatment plant during the May sampling also suggests that this facility may be contributing organic sediment to Stinson Creek during critical low flow periods.

The Fulton Wastewater Treatment Plant is contributing to the nutrient loads in Stinson Creek, but the historical data suggest that low dissolved oxygen also exists upstream of the wastewater treatment plant. Other sources in the watershed may be contributing to these problems (see Section 3 Source Inventory). Possible causes for the low dissolved oxygen concentrations upstream may include algal growth or nonpoint source loads of substances that cause biochemical oxygen demand. Nonpoint sources in the Stinson Creek watershed include runoff from agricultural and urban areas, septic systems, and riparian corridor conditions.

Concentrations of other parameters in the wastewater treatment plant effluent (e.g., ammonia and biochemical oxygen demand) were well below permit limits during both the May and September sampling and were likely not directly contributing to the observed low dissolved oxygen.

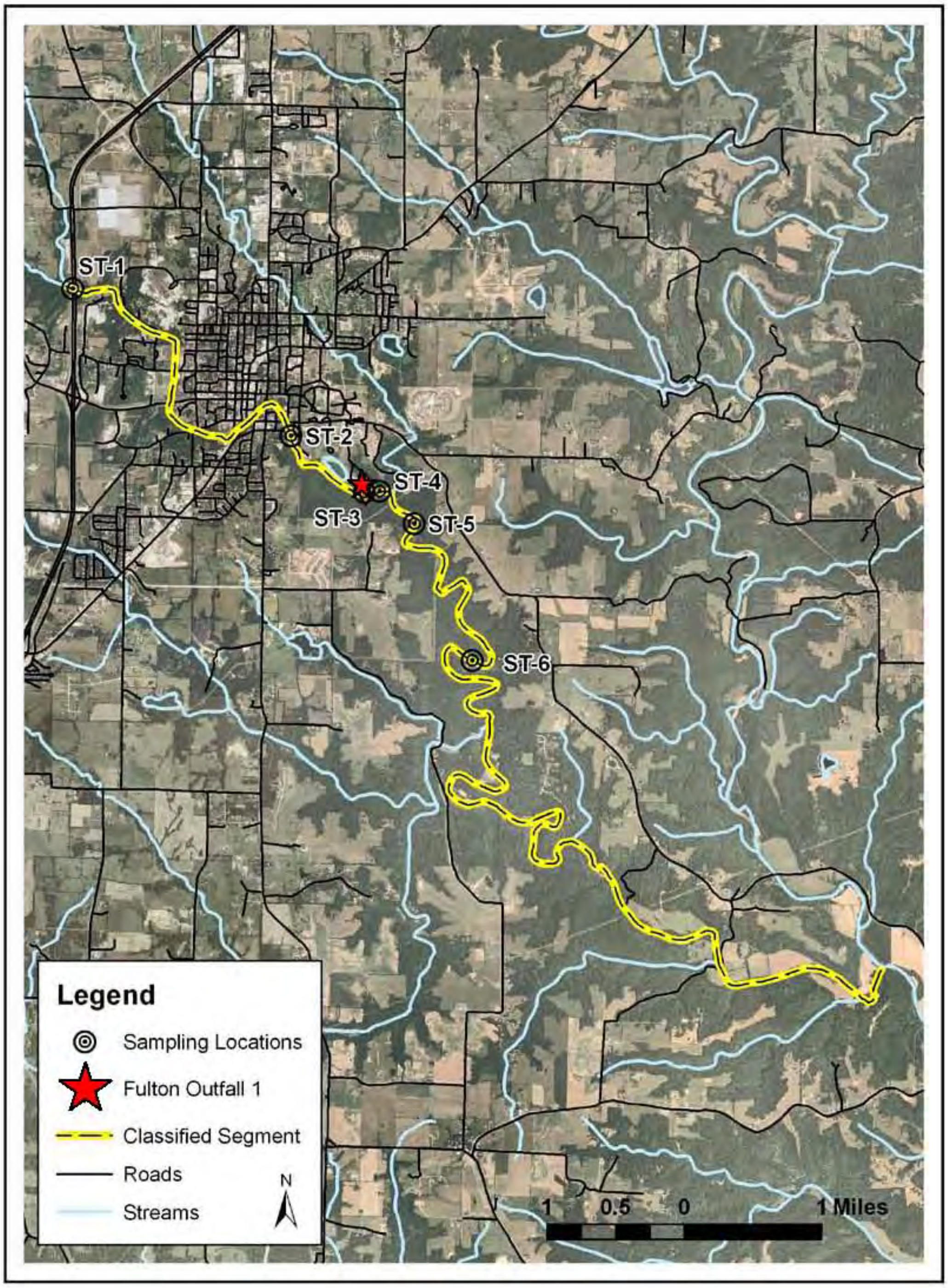

Figure 4. Location of sampling sites in the Stinson Creek watershed.

Table 5. Stinson Creek water quality data collected on May 20, 2008. Average flow during this event was 2 cubic feet per second (cfs).

Sampling Location (Time)	Location	Chlorophyll a (µg /L)	CBOD5 (mg/L)	Nitrogen, Ammonia (mg/L)	Nitrogen, TKN (mg/L)	Nitrogen, NO2+NO3 (mg/L)	DO (mg/L)	pH	Temp. (°C)	TP (mg/L)	TSS (mg/L)
ST-1 (5:36PM)	3.3 mi above WWTP	10	<2	<1	0.72	<1	10.98	7.46	19.41	0.006	8
ST-2 (4:36PM)	0.74 mi above WWTP	7	<2	<1	0.58	<1	12.47	8.26	21.51	0.006	<5
ST-3 (2:28PM)	Fulton WWTP	No Data	3	<1	1.4	17	8.03	7.48	18.75	3.1	8
ST-4 (2:52PM)	0.1 mi below WWTP	304	6.1	<1	2.4	6.8	14.70	8.31	20.85	1.4	25
ST-5 (4:00PM)	0.6 miles below Smith Branch	251	5.6	<1	2.8	4	16.83	8.81	21.39	0.88	14
ST-6 (1:40PM)	2.2 mi below WWTP	299	4.7	<1	1.2	2.6	20.06	8.94	20.12	0.69	15

Notes: ND = Non-Detect; CBOD5 = Carbonaceous Biochemical Oxygen Demand (5 days); TKN = Total Kjeldahl Nitrogen; NO2+NO3 = Nitrite + Nitrate; DO = Dissolved Oxygen; Temp. = Temperature; TP = Total Phosphorus; TSS = Total Suspended Solids

Table 6. Stinson Creek water quality data collected on September 10, 2008. Average flow during this event was 9 cubic feet per second (cfs).

Sampling Location (Time)	Location	Chlorophyll a (µg /L)	CBOD5 (mg/L)	Nitrogen, Ammonia (mg/L)	Nitrogen, TKN (mg/L)	Nitrogen, NO2+NO3 (mg/L)	DO (mg/L)	pH	Temp. (°C)	TP (mg/L)	TSS (mg/L)
ST-1 (8:25AM)	3.3 mi above WWTP	7	2.9	0.61	0.85	<1	8.14	7.49	16.87	0.05	16
ST-2 (9:45AM)	0.74 mi above WWTP	7	<2	0.86	0.95	<1	9.04	7.76	17.4	0.05	18
ST-3 (10:20AM)	Fulton WWTP	No Data	2.8	0.63	0.7	2.4	7.74	7.76	21.15	0.94	19
ST-4 (11:25AM)	0.1 mi below WWTP	51	3.1	0.11	1.2	1.5	8.43	7.89	19.97	0.92	11
ST-5 (11:00AM)	0.6 miles below Smith Branch	38	2.1	0.60	1.3	0.99	9.51	8.04	18.78	0.48	17
ST-6 (12:00PM)	2.2 mi below WWTP	34	<2	<1	0.1	0.76	9.83	8.21	18.08	0.35	8

Notes: CBOD5 = Carbonaceous Biochemical Oxygen Demand (5 days); TKN = Total Kjeldahl Nitrogen; NO2+NO3 = Nitrite + Nitrate; DO = Dissolved Oxygen; Temp. = Temperature; TP = Total Phosphorus; TSS = Total Suspended Solids

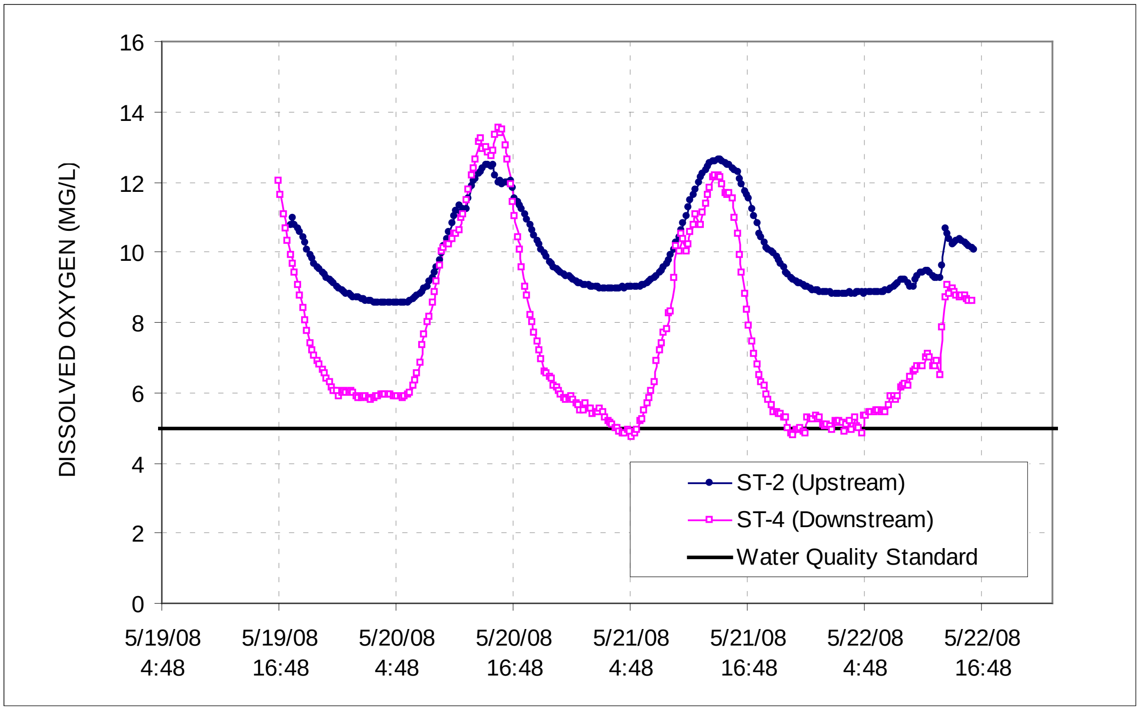

Figure 5. **Continuous dissolved oxygen data observed at Stinson Creek 2 and Stinson Creek 4 during late May 2008.**

Note: Continuous data for the Stinson Creek control site were not recorded due to equipment malfunction.

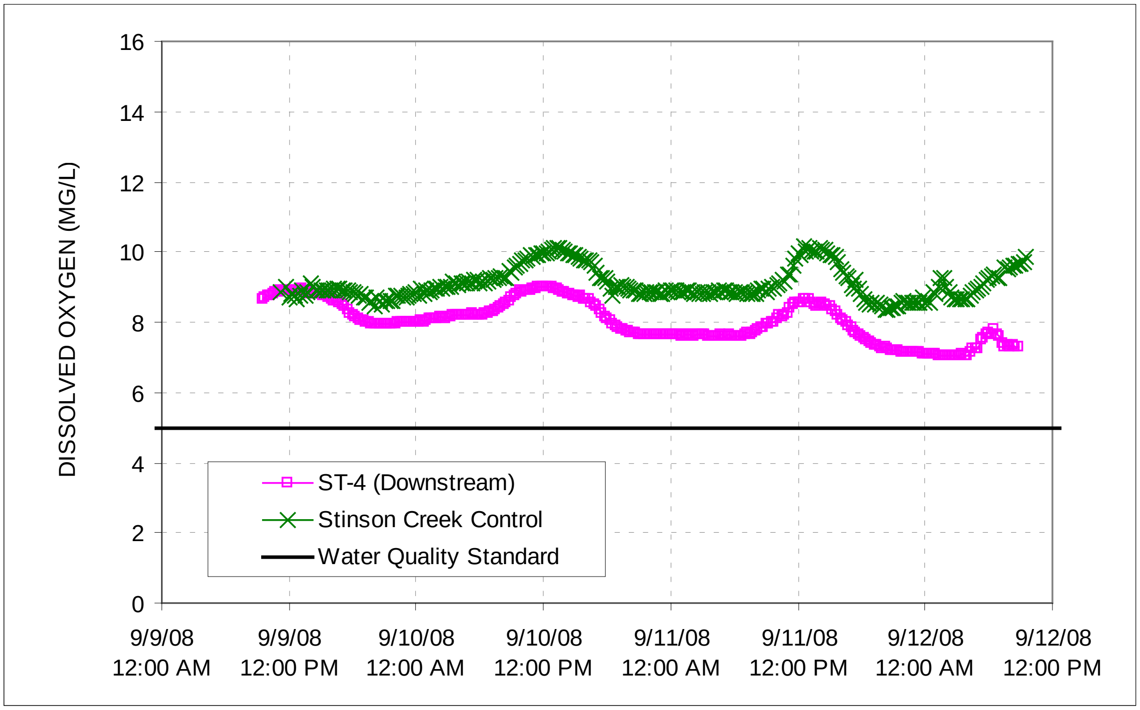

Figure 6. **Continuous dissolved oxygen data observed at Stinson Creek 4 and the control sampling location[6] during early September 2008**

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[6] Data from the control site was not used in EPA's modeling and is not included in this TMDL.

5.2 TMDL Modeling[7]

Dissolved oxygen in streams is determined by the factors of photosynthetic productivity, respiration (autotrophic and heterotrophic), reaeration, and temperature. These factors are influenced by natural and anthropogenic conditions within a watershed. Generally, reaeration is based on the physical properties of the stream and on the capacity of water to hold dissolved oxygen. This capacity is mainly determined by water temperature with colder water having a higher saturation concentration for dissolved oxygen. In a review of variables and their importance in dissolved oxygen modeling Nijboer and Verdonschot (2004) categorized the impact of a number of variables on oxygen depletion. For this TMDL, the effects of temperature and the physical aspects of the stream itself were discounted. Even though the hydrological regime of historic prairie streams was modified by changes in land cover and channelization, manipulation of these parameters does not address a pollutant and so is not the goal of a TMDL. Pollutants which result in oxygen concentrations below saturation are:

- fine particle size of bottom sediment
- high nutrient levels (nitrogen and phosphorus)
- suspended particles of organic matter

Because these three variables vary to a large extent based on anthropogenic influences they are appropriate targets for a TMDL written to address an impairment of low dissolved oxygen.

Total suspended solids consist of fine particles of both organic and inorganic solids suspended in the water column. Since fine particle-sized organic bottom sediments and suspended particles of organic matter are derived from similar loading conditions of terrestrial and stream bank erosion, this TMDL will have as one of its allocations total suspended solids (see Appendix B for discussion of development of suspended solids targets). This target was derived based on a reference approach by targeting the 25th percentile of total suspended sediment measurements (U.S. Geological Survey, or USGS, non-filterable residue) in the geographic region in which Stinson Creek is located (see Appendix A.3 for a list of sites and data). To address nutrient levels, the EPA nutrient ecoregion reference concentrations were used. For the ecoregion where Stinson Creek is located, the reference concentration for total nitrogen[8] is 0.855 mg/L, and the reference concentration for total phosphorus is 0.092 mg/L (EPA 2001a and EPA 2001b). This TMDL will not specifically target chlorophyll *a* as a wasteload allocation, but will use a linkage between nutrient concentrations and chlorophyll response to achieve the ecoregion reference concentrations.

5.2.1 Load Duration Curves

To develop load duration curves for total nitrogen and total phosphorus, a method similar to that used for total suspended solids (Appendix B) was employed. First, total nitrogen and total phosphorus measurements were collected from USGS sites in the vicinity of the impaired stream. This data was adjusted such that the median of the measured data was equal to the ecoregion

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[7] EPA Region 7 performed the modeling for this TMDL

[8] Total Kjeldahl nitrogen and nitrate plus nitrite as nitrogen

reference concentration. This was accomplished by subtracting the difference of the data median and the reference concentration. Where this would result in a negative concentration, the data point in question was replaced with the minimum concentration seen in the measured data. This resulted in a modeled data set which retained much of the original variability seen in the measured data. This modeled data was then regressed as instantaneous load versus flow. The resultant regression equation was used to develop the load duration curve.

To develop the TMDL expression of maximum daily loads, the background discharge at the stream outlet was modified from the traditional approach using synthetic flow estimation. Since the design flow from permitted facilities would overwhelm the background natural low flow, the sum of permitted volumes was added to the derived stream discharge at all percentiles of flow to take into account the increases in flow volume as well as pollutant load. The TMDL curves in the load duration curves flatten at low flow because at these lower flows the TMDL target is dominated by the point source flow.

5.2.2 QUAL2K

An essential component of developing a TMDL is establishing a relationship between the source loadings and the resulting water quality. For this TMDL, the relationship between the source loadings of biochemical oxygen demand and nutrients on dissolved oxygen is generated by the water quality model QUAL2K (Chapra et al., 2007).

QUAL2K is supported by EPA and it and its predecessor (QUAL2E) have been used extensively for TMDL development and point source permitting issues across the country, especially for dissolved oxygen studies. QUAL2K is well accepted within the scientific community because of its proven ability to simulate the processes important to dissolved oxygen conditions within streams. The QUAL2K model is suitable for simulating the hydraulics and water quality conditions of a small river. It is a one-dimensional model with the assumption of a completely mixed system for each computational cell. QUAL2K assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the longitudinal direction of flow. The model allows for multiple waste discharges, water withdrawals, tributary flows, and incremental inflows and outflows. The processes employed in QUAL2K address nutrient cycles, algal growth, and dissolved oxygen dynamics. Once the QUAL2K model was setup and calibrated for Stinson Creek, a series of scenarios were run to evaluate the pollutant load reductions needed to achieve the dissolved oxygen criteria. These results are summarized in Table 10, and a detailed discussion of the QUAL2K model is included in Appendix C.

6 Calculation of Load Capacity

Load capacity, or LC, is defined as the greatest amount of loading of a pollutant that a water body can receive without violating water quality standards. This load is then divided among the point source (wasteload allocation, or WLA) and nonpoint source (load allocation, or LA) contributions to the stream, with an allowance for an explicit margin of safety, or MOS. If the margin of safety is implicit, no numeric allowance is necessary. This is expressed in the following manner:

$$LC = \sum WLA + \sum LA + MOS$$

The wasteload allocation and load allocation are calculated by multiplying the appropriate flow in cfs by the appropriate pollutant concentration in mg/l. A conversion factor of 5.395 is used to convert the units (cfs and mg/L) to pounds per day (lbs/day).

(stream flow in cfs)(maximum allowable pollutant concentration in mg/L)(5.395)= pounds/day

Critical conditions are considered when the load capacity is calculated. Organic sediment and dissolved oxygen levels that threaten the integrity of aquatic communities generally occur during low flow periods, so these periods are considered the critical conditions.

7 Load Allocation (Nonpoint Source Load)

The load allocations include all existing and future nonpoint sources and natural background contributions (40 CFR § 130.2(g)). The load allocations for the Stinson Creek TMDL are for all nonpoint sources of total phosphorus, total nitrogen and total suspended solids, which could include loads from agricultural lands, runoff from urban areas outside of the Fulton municipal separate storm sewer system, livestock, and failing onsite wastewater treatment systems. The load allocations are provided in Tables 7 through 9 and were calculated based on the total of all headwater and lateral inflow loads used in the QUAL2K model for the allocation scenario model run. The load allocations are intended to allow the dissolved oxygen target and the organic sediment narrative criteria to be met at all locations within the stream. During critical conditions when flow is at its lowest, and there is effectively no flow from nonpoint sources, the load allocations for all targeted pollutants is zero pounds per day.

8 Wasteload Allocation (Point Source Loads)

The wasteload allocation is the portion of the load capacity that is allocated to existing or future point sources of pollution. The sum of the design flows of all site-specific permitted dischargers with Missouri State Operating Permits (Table 3) in the Stinson Creek watershed, including the Fulton Wastewater Treatment Plant, is 8.56 million gallons per day. This does not include Fulton's municipal separate storm sewer system. To meet the targeted nutrient and total suspended solids critical condition targets outlined in this TMDL, the sum of the wasteload allocations was calculated by using nutrient ecoregion reference concentrations and 25th percentile total suspended solids concentrations, and the sum of the design flows of all permitted facilities in the watershed (with the exception of the municipal separate storm sewer system).

The municipal separate storm sewer system wasteload allocation is set based on the percentage of the watershed covered under the municipal separate storm sewer system permit. The entire Stinson Creek watershed is calculated at 45.97 square miles using the BASINS 4 modeling program and the municipal separate storm sewer system area at 11.3 square miles using the 2000 census layer for the city boundary which overlaps the watershed. This results in the municipal separate storm sewer system permit receiving a wasteload allocation equivalent to 25% of the diffuse load to the stream. Therefore, the municipal separate storm sewer system wasteload allocation increases at higher storm flows as available diffuse flow increases.

The load duration curves for the targeted pollutants are depicted in Figures 7 through 9, where the TMDL line represents the total load capacity of all point and nonpoint sources of pollutants. The pollutant allocations under a range of flow conditions are outlined in Tables 7 through 9.

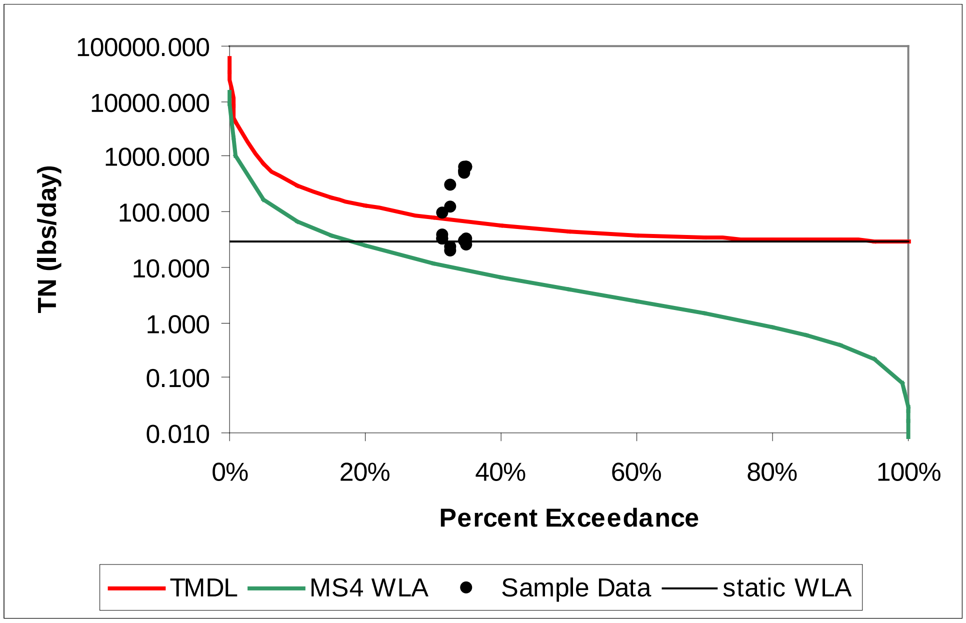

Figure 7. Load Duration Curve – Total Nitrogen.

Table 7. Total Nitrogen Allocations (lbs/day)

Percent Exceedance	Flow (cfs)	TMDL (LC)	WLA Fulton WWTP	WLA Fulton MS4	WLA (other permits)	LA
100	6.14	28.31	20.95	0	7.36	0
80	6.81	31.42	20.95	0.78	7.36	2.33
60	8.15	37.62	20.95	2.33	7.36	6.98
40	11.75	54.22	20.95	6.48	7.36	19.43
20	26.59	122.66	20.95	23.59	7.36	70.76

Note: MS4 = Municipal separate storm sewer system

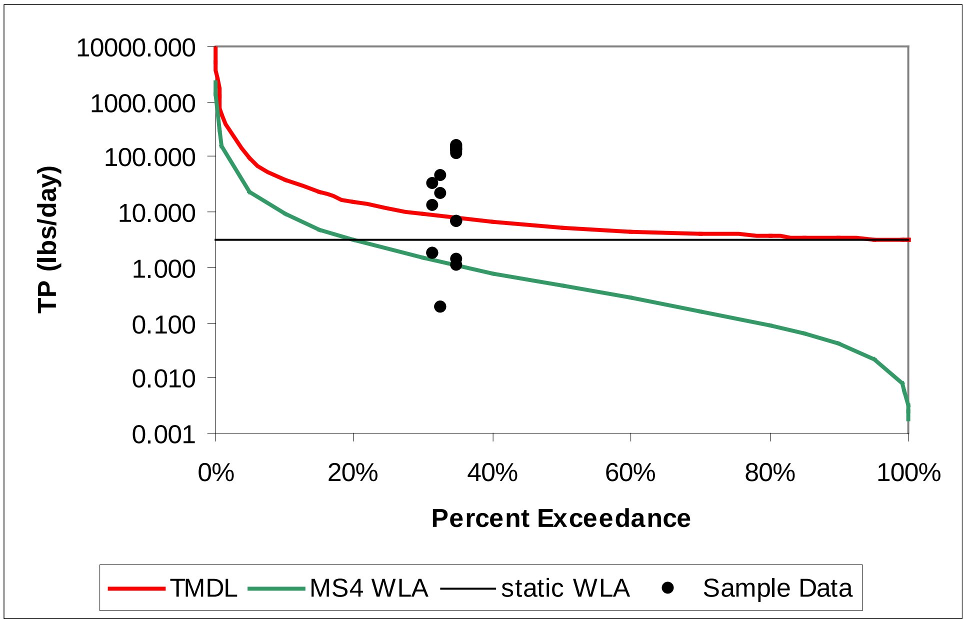

Figure 8. Load Duration Curve – Total Phosphorus.

Table 8. Total Phosphorus Allocations (lbs/day)

Percent Exceedance	Flow (cfs)	TMDL (LC)	WLA Fulton WWTP	WLA Fulton MS4	WLA (other permits)	LA
100	6.14	3.04	2.25	0	0.79	0
80	6.81	3.60	2.25	0.09	0.79	0.47
60	8.15	4.48	2.25	0.28	0.79	1.15
40	11.75	6.68	2.25	0.80	0.79	2.83
20	26.59	15.78	2.25	3.04	0.79	9.70

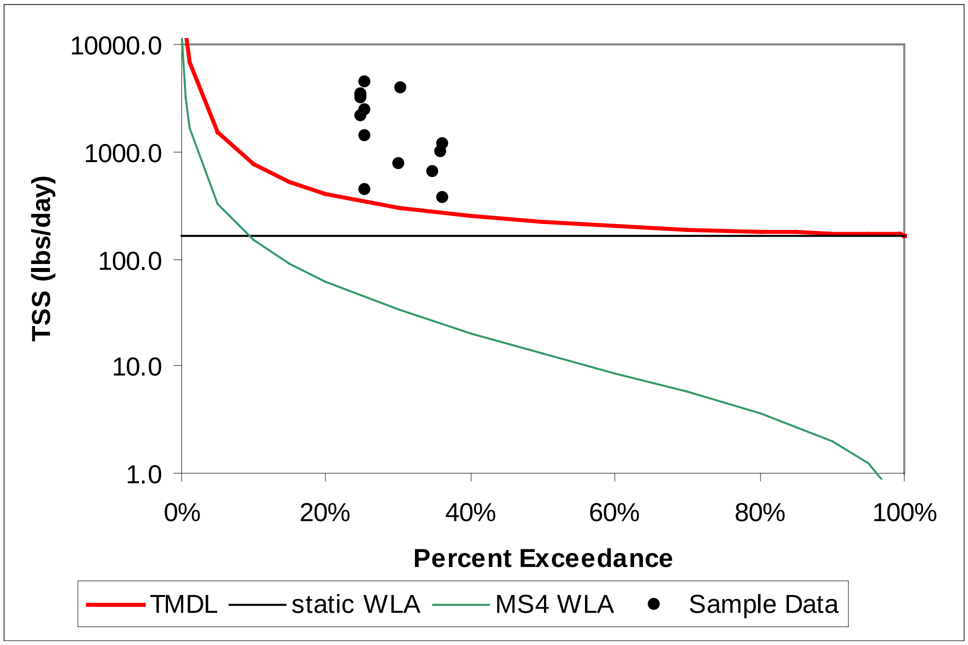

Figure 9. Load Duration Curve – Total Suspended Solids.

Table 9. Total Suspended Solids Allocations (lbs/day)

Percent Exceedance	Flow (cfs)	TMDL (LC)	WLA Fulton WWTP	WLA Fulton MS4	WLA (other permits)	LA
100	6.14	165.57	122.51	0	43.06	0
80	6.67	179.81	122.51	3.56	43.06	10.68
60	7.42	200.16	122.51	8.65	43.06	25.94
40	9.14	246.43	122.51	20.22	43.06	60.64
20	15.10	407.26	122.51	60.42	43.06	181.27

New wasteload allocations for the Fulton Wastewater Treatment Plant were calculated through the modeling process and are shown in Table 10. The wasteload allocations for total nitrogen, total phosphorus and total suspended solids were derived from the load duration curves at low flow, when inputs are set at the facility design flow of 4.54 cubic feet per second. The wasteload allocation for biochemical oxygen was derived from the QUAL2K modeling that resulted in meeting water quality standards.

The other permitted facilities in the Stinson Creek watershed each discharge an insignificant volume of effluent compared to the Fulton Wastewater Treatment Plant and are also unlikely to discharge during the critical low flow periods. It is during periods of low flow that water quality is most likely to be impacted by loadings of organic sediment and other substances that can contribute to low dissolved oxygen. Their wasteload allocations will therefore remain equal to existing permit limits.

Table 10. Waste Load Allocations for Fulton Wastewater Treatment Plant

Pollutant	Concentration Limits	WLA at Design Flow (4.54 cfs)
TN	0.855 mg/L	20.95 lbs/day
TP	0.092 mg/L	2.25 lbs/day
TSS	5 mg/L	122.51 lbs/day
$CBOD_5$	9 mg/L	220 lbs/day

9 Margin of Safety

A margin of safety is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems. The margin of safety is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the margin of safety can be achieved through one of two approaches:

(1) Explicit - Reserve a portion of the load capacity as a separate term in the TMDL.
(2) Implicit - Incorporate the margin of safety as part of the critical conditions for the wasteload allocation and the load allocation calculations by making conservative assumptions in the analysis.

An implicit margin of safety was incorporated into the TMDL based on conservative assumptions applied to the QUAL2K model and used in the development of the TMDL load duration curves. Among the conservative approaches used was to calculate wasteload allocations by targeting the 25th percentile of total suspended solids concentrations in the geographic region in which Stinson Creek is located, and to establish wasteload allocations for the Fulton Wastewater treatment Plant under critical low flow conditions when discharge from this facility will dominate the stream flow.

10 Seasonal Variation

Federal regulations at 40 CFR §130.7(c)(1) require that TMDLs take into consideration seasonal variation in applicable standards. The Stinson Creek TMDL addresses seasonal variation in two ways. One is by identifying a loading capacity that is protective of the critical low flow period sampled in May 2008. Even though May is not a typical low flow month, the sampling occurred during an abnormally low flow period in which dissolved oxygen concentrations did not meet water quality standards and there were lower flows than those observed during September 2008. QUAL2K TMDL development for low dissolved oxygen during critical low-flow conditions are expected to be protective year round.

The second way in which the Stinson Creek TMDL takes seasonal variation into account is through the use of load duration curves. Load duration curves represent the allowable pollutant load under different flow conditions and across all seasons. The results obtained using the load duration curve method are more robust and reliable over all flows and seasons when compared with those obtained under critical low-flow conditions.

11 Monitoring Plan for TMDLs Developed under Phased Approach

Post-TMDL monitoring will be scheduled and carried out by the Department about three years after the TMDL is approved, or in a reasonable period of time following the compliance schedule outlined in the permit and the application of any new effluent limits. The Missouri State Operating Permit for the city of Fulton's wastewater treatment plant was reissued August 12, 2005 and expires August 11, 2010. The permit will be renewed at that time with new effluent limits based on the wasteload allocations developed in this TMDL.

The permit currently requires instream monitoring downstream of the wastewater treatment plant. This requirement will be carried over at permit renewal in order to provide additional data with which to assess the impact of the revised permit limits on Stinson Creek. Instream data currently collected monthly in Stinson Creek includes dissolved oxygen, pH, ammonia and temperature. Also, the local Stream Team has gathered chemistry data on Stinson Creek above the wastewater treatment plant several times a year between 1998 and 2005. These two sources of data (permittee instream monitoring and volunteer monitoring) will be used for screening purposes, to compare the stream's current condition with future, post-TMDL, conditions. The wastewater treatment plant instream monitoring data are included in Appendix A.

Additionally, the Department will routinely examine physical habitat, water quality, invertebrate community, and fish community data collected by other state and federal agencies in order to assess the effectiveness of TMDL implementation. One example is the Resource Assessment and Monitoring Program administered by the Missouri Department of Conservation. This program randomly samples streams across Missouri on a five to six year rotating schedule.

12 Implementation Plans

Since low dissolved oxygen is an issue in Stinson Creek both upstream and downstream of the Fulton Wastewater Treatment Plant, addressing the sources of impairment in Stinson Creek will require developing nonpoint source, as well as point source, controls in the watershed. However, due to issues regarding low dissolved oxygen as a natural background condition, the department may develop revised dissolved oxygen criteria for Stinson Creek and similar streams during future triennial reviews of the Water Quality Standards. The department acknowledges that, should revised criteria be developed, a revised Stinson Creek TMDL may be necessary. It also acknowledges that the revised criteria may result in no difference for Stinson Creek and that new loading calculations may not differ or offer relief from what is currently contained in this TMDL.

12.1 Point Sources

This TMDL will be implemented partially through permit action. When it was last renewed, the operating permit for the city of Fulton's wastewater treatment plant carried over the biochemical oxygen demand and total suspended solids effluent limits for Outfall #001 from the previous permit. Those limits are 45 mg/L weekly average and 30 mg/L monthly average for both biochemical oxygen demand and total suspended solids.

Wasteload allocations developed for this TMDL will be used to derive new effluent limitations for carbonaceous biochemical oxygen demand ($CBOD_5$). Becauseorganic sediment is one component of total suspended solids (TSS), wasteload allocations will also be developed for TSS that reduce organic sediment and are protective of the dissolved oxygen criterion and aquatic life use in Stinson Creek. Based on a review of discharge monitoring report data submitted by the Fulton WWTP, it appears that in most cases monthly average biochemical oxygen demand concentrations measured in the effluent from Outfall #001 already meet or are below the carbonaceous biochemical oxygen demand wasteload allocation of 9 mg/L outlined in Table 10 of this TMDL. These data would seem to suggest that major upgrades to the wastewater treatment plant may not be required at this time in order to meet $CBOD_5$ wasteload allocations.

The Department anticipates numeric and narrative water quality criteria will be met after the new effluent limits for $CBOD_5$ and TSS have been applied to the Fulton Wastewater Treatment Plant. Implementation of these effluent limits will require continued proper operation and maintenance of the facility, and may include upgrades and improvements to address reductions in $CBOD_5$ and TSS. Upgrades will also include the elimination of Outfall #002 that is planned for the next permit cycle. Effluent monitoring for nutrient species and instream monitoring for dissolved oxygen, temperature, pH, ammonia and chlorophyll *a* will also be required on the Fulton Wastewater Treatment Plant operating permit. Additional monitoring and analysis may be conducted by either the department or the city to determine whether the dissolved oxygen minimum criterion of 5 mg/L found in 10 CSR 20-7.031, Table A is appropriate or if a site-specific dissolved oxygen criterion is required. Any such evaluation would likely coincide with the Department's triennial review of the Water Quality Standards, when a new dissolved oxygen criterion may be promulgated.

If post-TMDL monitoring indicates that point source reductions are not achieving the desired improvements in water quality, the department will reevaluate the TMDL for further appropriate actions. These actions may include additional permit conditions on the Fulton Wastewater Treatment Plant (including effluent limits for total nitrogen and total phosphorus), revised permit conditions on the Fulton municipal separate storm sewer system and other facilities, and further control of nonpoint sources through a nonpoint source management plan.

12.2 Nonpoint Sources

While this document identifies several potential contributors to nonpoint source pollution in the Stinson Creek watershed, modeling analysis identifies very little reduction in nonpoint source load allocations relative to the significant reductions in wasteload allocations recommended.

Although the TMDL will be implemented through permit action, if the wasteload allocations do not achieve desired improvements in water quality, the Department may need to consider implementing efforts to reduce nonpoint source contributions. With cropland and grassland (potentially used for livestock grazing) accounting for roughly 58 percent of the land area in the watershed, agricultural runoff is likely to be a chief component of any potential nonpoint source contributions.

To further reduce the loading and the effect of nutrients and organic sediment on Stinson Creek, efforts would be made to encourage farmers to adopt best management practices, or BMPs. BMPs are recommended methods, structures, and practices designed to prevent or reduce water pollution. The concept of BMPs is one of a voluntary and site-specific approach to water quality problems. In the Stinson Creek watershed, agricultural BMPs should focus on irrigation and water management, nutrient management, riparian buffers, and erosion control.

In an effort to most effectively implement these BMPs, the Department may work with the Natural Resources Conservation Service, or NRCS, and the local Soil and Water Conservation District, or SWCD, to encourage area farmers to implement these practices on their land. An additional approach may also be to work with the NRCS and SWCD to form a watershed group comprised of local stakeholders with a common interest in protecting water quality in Stinson Creek.

13 Reasonable Assurances

The Department has the authority to issue and enforce Missouri State Operating Permits. Inclusion of effluent limits determined from the wasteload allocations established by the TMDL into a state permit, along with effluent monitoring reported to the Department, should provide a reasonable assurance that instream water quality standards will be met. The Department will work with the city of Fulton to discuss treatment plant upgrades and funding options and will issue a permit reflective of the water quality standards that must be met.

In most cases, “Reasonable Assurance” in reference to TMDLs relates only to point sources. As a result, any assurances that nonpoint source contributors of low dissolved oxygen will implement measures to reduce their contribution in the future will not be found in this section. Instead, discussion of reduction efforts relating to nonpoint sources can be found in the “Implementation” section of this TMDL.

14 Public Participation

This water quality limited segment of Stinson Creek is included on the EPA-approved 2008 303(d) List for Missouri. The public notice period for the draft Stinson Creek TMDL was from September 28, 2009 to November 11, 2009. Groups and individuals that received the public notice announcement include the Missouri Clean Water Commission, the Department’s Water Quality Coordinating Committee, the Missouri Department of Conservation’s Policy Coordinating Unit, Stream Team volunteers in Callaway County, the City of Fulton Utility

Department, the Callaway County Soil and Water Conservation District, the Callaway County Commission, the Mayor of Fulton and the two state legislators representing Callaway County. Finally, the public notice, the TMDL Information Sheet, and this document were posted on the Department Web site, making them available to anyone with Internet access. Comments received, and the Department's response to those comments, have been placed in the Stinson Creek administrative record file, as noted below.

15 Administrative Record and Supporting Documentation

An administrative record on the Stinson Creek TMDL has been assembled and is being kept on file with the Department. It includes the following:

- Fulton Wastewater Treatment Plant State Operating Permit MO-0103331
- Upper Stinson Creek Water Quality Study, August 2007, by Water Protection Program, Water Quality Monitoring and Assessment Section
- Stream Survey Reports
- Fulton Wastewater Treatment Plant Discharge Monitoring Report
- Stinson Creek Stream Team survey data
- Field data sheets and continuous dissolved oxygen data collected by Tetra Tech, May/September 2008.
- QUAL2K input and output files
- Stinson Creek TMDL Information Sheet
- Public notice announcement
- TMDL comments and comment responses

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Appendix A
Stinson Creek Water Quality Data
Appendix A.1 – Historic Data
Collected by the Missouri Department of Natural Resources and EPA 1991-2007

Site	Site Name	Year	Mo	Day	Time	Flow	C	DO	pH	SC	TKN	NH3N	NO3N	TN	TP	CBOD
710/11.0	Stinson Cr. 0.1 mi.bl. Fulton WWTP	1991	10	25	736	1.2	19	3.8		1600		0.02499	0.81			1.99
710/11.2	Stinson Cr. 0.1 mi.ab. Fulton WWTP	1991	10	25	725	0.2	16	2.7		1900		0.02499	0.02499			1.99
710/7.3	Stinson Cr. 3.8 mi.bl. Fulton WWTP	1991	10	25	805	1.3	16	6.6		1200		0.02499	0.098			1.99
710/11.0	Stinson Cr. 0.1 mi.bl. Fulton WWTP	1993	9	15	735	3.6	22	5.4	7.6	1270		0.04	11.7			1.2
710/11.0	Stinson Cr. 0.1 mi.bl. Fulton WWTP	1993	9	15	1545		24	8.3	7.6	1517		0.0199	14.6			1.6
710/11.0	Stinson Cr. 0.1 mi.bl. Fulton WWTP	1993	9	16	705		22	5.4	7.6	1424		0.06	10.15			1.6
710/11.0	Stinson Cr. 0.1 mi.bl. Fulton WWTP	1993	9	16	1500		24	8.4	7.6	1492		0.0199	11.65			1.8
710/11.0	Stinson Cr. 0.1 mi.bl. Fulton WWTP	1993	9	17	730		20	5.4	7.4	1370		0.0199	8.77			2.3
710/11.0	Stinson Cr. 0.1 mi.bl. Fulton WWTP	1993	9	17	1509		24	8.5	7.6	1568		0.0199	11.25			1.6
710/11.1	Fulton WWTP outfall 001	1993	9	14	1110	2						0.0199	16.4			1.3
710/11.1	Fulton WWTP outfall 001	1993	9	15	1013		23	7.6	7.6	1469						
710/11.1	Fulton WWTP outfall 001	1993	9	15	1015	2						0.0199	15			1.6
710/11.1	Fulton WWTP outfall 001	1993	9	16	1135		22	7.7	7.5	1488						
710/11.1	Fulton WWTP outfall 001	1993	9	16	1130	1.7						0.0199	12.2			0.499
710/11.1	Fulton WWTP outfall 001	1993	9	17	1030			6.9	7.7	1517						
710/11.2	Stinson Cr. 0.1 mi.ab. Fulton WWTP	1993	9	15	722	0.3	20	4.8	7.4	1233		0.0199	0.47			1.4
710/11.2	Stinson Cr. 0.1 mi.ab. Fulton WWTP	1993	9	15	1530		24	10.3	7.9	1415		0.0199	0.44			1.2
710/11.2	Stinson Cr. 0.1 mi.ab. Fulton WWTP	1993	9	16	654		21	5.4	7.4	1158		0.0199	0.34			1.1
710/11.2	Stinson Cr. 0.1 mi.ab. Fulton WWTP	1993	9	16	1457		24	10.1	7.5	979		0.0199	0.35			1.8
710/11.2	Stinson Cr. 0.1 mi.ab. Fulton WWTP	1993	9	17	720		20	5.7	7.1	985		0.0199	0.28			0.499
710/11.2	Stinson Cr. 0.1 mi.ab. Fulton WWTP	1993	9	17	1525		22	10.2	7.5	944		0.0199	0.29			0.499
710/7.3	Stinson Cr. 3.8 mi.bl. Fulton WWTP	1993	9	15	823	2.5	20	6.6	7.7	1294		0.0199	3.08			0.499
710/7.3	Stinson Cr. 3.8 mi.bl. Fulton WWTP	1993	9	15	1455		22	12.3	8.2	1500		0.0199	3.42			1.5
710/7.3	Stinson Cr. 3.8 mi.bl. Fulton WWTP	1993	9	16	755		21	6.4	7.7	1339		0.0199	6.15			1.5

Site	Site Name	Year	Mo	Day	Time	Flow	C	DO	pH	SC	TKN	NH3N	NO3N	TN	TP	CBOD
710/7.3	Stinson Cr. 3.8 mi.bl. Fulton WWTP	1993	9	16	1420		24	12.2	8.2	1409		0.0199	6.66			1.4
710/7.3	Stinson Cr. 3.8 mi.bl. Fulton WWTP	1993	9	17	653		20	6.5	7.7	1328		0.0199	9.02			0.499
710/7.3	Stinson Cr. 3.8 mi.bl. Fulton WWTP	1993	9	17	1430		23	12.2	8.2	1435		0.0199	9.32			0.499
717/0.1	Smith Branch nr. Mouth	1993	9	15	740	0.02	20	6.7	7.4	519		0.0199	0.07			0.499
717/0.1	Smith Branch nr. Mouth	1993	9	15	1548		22	9.7	7.9	527		0.0199	0.0199			1.3
717/0.1	Smith Branch nr. Mouth	1993	9	16	708		20	6.4	7.5	557		0.0199	0.0199			1
717/0.1	Smith Branch nr. Mouth	1993	9	16	1513		23	9.8	7.6	552		0.0199	0.0199			0.499
717/0.1	Smith Branch nr. Mouth	1993	9	17	736		19	7	7.4	562		0.0199	0.0199			0.499
717/0.1	Smith Branch nr. Mouth	1993	9	17	1513		22	9.4	7.5	567		0.0199	0.0199			0.499
710/10.6	Stinson Cr. 0.5 mi.bl. Fulton WWTP	1999	9	3				5.8								
710/10.7	Stinson Cr. 0.4 mi.bl. Fulton WWTP	1999	9	3			23	6								
710/11.0	Stinson Cr. 0.1 mi.bl. Fulton WWTP	1999	9	3		2	22	5.8		1490		0.02499	23.7		5.72	
710/11.2	Stinson Cr. 0.1 mi.ab. Fulton WWTP	1999	9	3		0	22	3.1		675		0.02499	0.02499		0.04	
710/10.7	Stinson Cr. 0.4 mi.bl. Fulton WWTP	1999	10				13	8.1								
710/10.8	Stinson Cr. 0.3 mi.bl. Fulton WWTP	1999	10				13	6.4								
710/10.9	Stinson Cr. 0.2 mi.bl. Fulton WWTP	1999	10				14	7.7								
710/11.0	Stinson Cr. 0.1 mi.bl. Fulton WWTP	1999	10				14	7.7								
710/11.2	Stinson Cr. 0.1 mi.ab. Fulton WWTP	1999	10				10	4.7								
710/10.7	Stinson Cr. Above Smith Branch	2001	8	16	1425	2.7	25	7.1	8	1560	1.48	0.07	22.1		4.94	0.999
710/10.7	Stinson Cr. Above Smith Branch	2001	8	17	645	2.6	21	4.7	7.8	1590	0.0999	0.12	20.1		4.88	0.999
710/10.9	Stinson Cr. 0.2 mi.bl. Fulton WWTP	2001	8	16	1405	0.3	24	10.3	8	1730	0.72	0.02499	0.33		0.02499	2
710/10.9	Stinson Cr. 0.2 mi.bl. Fulton WWTP	2001	8	17	705	0.3	20	4.8	7.8	1600	0.85	0.05	0.21		0.05	0.999
710/11.1	Fulton WWTP outfall 001	2001	8	16	1410	2.4	24	7.8	7.9	1640	0.0999	0.06	24.9		5.57	2
710/11.1	Fulton WWTP outfall 001	2001	8	17	700	2.3	23	6.8	8.1	1560	0.0999	0.02499	24.2		5.51	2
710/9.8	Stinson Cr. Below Smith Branch	2001	8	16	1340	3.3	25	12.8	8.4	1440	0.0999	0.02499	18.5		4.15	0.999
710/9.8	Stinson Cr. Below Smith Branch	2001	8	17	610	3.2	20	4.4	8.1	1610	0.22	0.02499	20.2		5.33	0.999
717/0.1	Smith Branch nr. Mouth	2001	8	16	1430	0.5	23	6.5	8	475	0.66	0.02499	0.07		0.13	0.999
717/0.1	Smith Branch nr. Mouth	2001	8	17	640	0.5	19	5.3	8.1	480	0.58	0.02499	0.07		0.11	0.999

Site	Site Name	Year	Mo	Day	Time	Flow	C	DO	pH	SC	TKN	NH3N	NO3N	TN	TP	CBOD
710/10.6	Stinson Cr. 0.5 mi.bl. Fulton WWTP	2002	8	8	657	1.5	20	3.9	7.9	1630		0.02499	23.4		5.84	0.99
710/10.6	Stinson Cr. 0.5 mi.bl. Fulton WWTP	2002	8	8	1310		25	12.9	8.4	1600	0.099	0.02499	22.9	23	4.76	0.99
710/11.0	Stinson Cr. 0.1 mi.bl. Fulton WWTP	2002	8	8	722	1.5	22	4.3	7.9	1620	0.94	0.02499	23.5	24.44	5.33	0.99
710/11.0	Stinson Cr. 0.1 mi.bl. Fulton WWTP	2002	8	8	1332		26	7.2	8.2	1620	0.099	0.02499	24.6	24.7	5.12	0.99
710/11.1	Fulton WWTP outfall 001	2002	8	8	730	1.5	24	6.1	7.8	1610	0.099	0.02499	24.5	24.6	5.33	0.99
710/11.1	Fulton WWTP outfall 001	2002	8	8	1346		25	7.1	8	1620	0.099	0.02499	24.8	24.9	5.35	0.99
710/11.2	Stinson Cr. 0.1 mi.ab. Fulton WWTP	2002	8	8	1353		26	4	8.2	635	0.94	0.02499	0.02499	0.96	0.02499	0.99
710/11.2	Stinson Cr. 0.1 mi.ab. Fulton WWTP	2002	8	8	732	0.02	18	4	7.5	916	1.16	0.02499	0.05	1.21	0.02499	0.99
710/11.9/0.2	Stinson Cr. @ Hwy O	2007	8	22	650		25.3	1.9	7.3	298	1.06	0.3	0.04	1.1	0.16	0.99
710/11.9/2.7	Stinson Cr. @ Hwy 54	2007	8	22	712	0	24.4	2	7.5	244	1.07	0.1	0.04	1.11	0.1	0.99
710/11.9/3.4	Stinson Cr. nr Trailer Park	2007	8	22	745	0	25	1.8	7.3	203	1.66	1.1	0.04	1.7	0.07	0.99
710/11.9/6.4	Stinson Cr. @ CR 217	2007	8	22	728		25	2.1	7.4	393	2.4	0.03	0.00499	2.41	0.15	0.99

See notes and definitions of abbreviations on the following page.

Additional information regarding the available Stinson Creek water quality data.

Sampling Entity	Type of Data	Used for Modeling?
MDNR	QA	No
EPA 1993	QA	No
Fulton WWTP - Instream	Screening	No

Notes:

Data from all years, except 1993, were collected by the Missouri Department of Natural Resources. Data from 1993 were data collected by EPA.

QA = These data are of sufficient quality to evaluate compliance with water quality standards and to support TMDL development because they were collected in accordance with required quality assurance procedures and Department sampling protocols.

Screening = These can only be used for screening purposes (i.e., not to evaluate compliance with water quality standards or to support TMDL development).

Empty cell means no data available.
ab. = above
bl. = below
C = temperature in degrees Celsius
CBOD = Carbonaceous Biochemical Oxygen Demand
DO = Dissolved Oxygen
NH3N = Ammonia as N
NO3N =nitrate +nitrite as nitrogen
SC = Specific Conductivity
TKN = Total Kjeldahl Nitrogen
TN = Total Nitrogen
TP = Total Phosphorus
WWTP = Wastewater treatment plant

For Department data all units are milligrams per liter except chlorophyll a is µg/L, specific conductivity is umhos/cm, turbidity is nephelometric units. Detection limits and non-detects are expressed as "less-than" numbers and show up in this list as those data ending in 99. Example: <2 will appear as 0.99.

Appendix A.2

Instream data collected by Fulton WWTP (Permit #MO-0103331) from 8/2005 to 1/2009

Date	Average Temp. (°C)	pH	Average NH3N (mg/L)	Average DO (mg/L)
8/31/2005	23	7.6		2.5
9/30/2005	19	8	0.19	5.6
10/31/2005	12	7.5	0.03	8.3
11/30/2005	16	7.7	0.3	8.5
12/31/2005	4	7.8	0.15	7.0
1/31/2006	4	7.8	0.15	<10
2/28/2006	5	7.8	0.14	14.4
3/31/2006				
4/30/2006	20	8.1	0.31	9
5/31/2006	19	7.7	0.18	8.4
6/30/2006	27	7.7	0.23	5
7/31/2006	27	7.7	0.23	5
8/31/2006	22.1	7.7	0.14	1.2
9/30/2006	23	8.3	0.13	6.7
10/31/2006	12	7.6	0.19	7.3
11/30/2006	11	7.9	0.1	14.2
12/31/2006	13	8	0.19	16.6
1/31/2007	2	7.8	0.49	16
2/28/2007	11	7.7	0.71	13.6
3/31/2007	10	8	0.43	11.9
4/30/2007	15.3	8.2	0.15	13.7
5/31/2007	19.6	7.8	0.51	8.4
6/30/2007	21.2	7.7	0.24	5.9
7/31/2007	26.3	7.9	0.09	4
8/31/2007	31	7.9	31	4.8
9/30/2007	21	8.1	0.13	9.2
10/31/2007	17.5	7.8	0.02	7.2
11/30/2007	6.4	7.8	0.09	8
12/31/2007	8.5	7.8	0.06	10.9
1/31/2008	8.7	7.2	0.22	11
2/29/2008	6.5	7.4	0.53	12
3/31/2008	9	7.8	0.06	10.6
4/30/2008	12.7	8.2	0.48	8.2
5/31/2008	17.3	8	0.03	
6/30/2008	23.6	7.8	0.14	
7/31/2008	23	7.9	0.14	
8/31/2008	28.3	7.91	0.1	7.9
9/30/2008	19.4	8.6	0.05	

10/31/2008	19.7	8	0.11	6.6
11/30/2008	19.7	8	0.17	4.3
12/31/2008	4.3	7.8	0.05	10.9
1/31/2009	7.7	8	0.19	10.8

Appendix A.3

Suspended solids and instantaneous discharge for reference targeting Data collected by USGS and provided by EPA

St. Francis River (07036100)			Lamine River (06907300)		
Date	Discharge (cfs)	NFR (mg/L)	Date	Discharge (cfs)	NFR (mg/L)
11/2/1999	45	0.5	11/8/1999	28	17
5/10/2000	150	5	5/2/2000	30	23
11/14/2000	171	5	7/11/2000	107	30
5/9/2001	177	5	11/21/2000	68	14
11/13/2001	96	58	5/2/2001	144	31
1/23/2002	234	5	7/11/2001	117	71
3/6/2002	781	5	11/6/2001	87	74
5/15/2002	2750	15	1/8/2002	51	10
7/15/2002	227	20	2/4/2002	526	68
9/4/2002	195	5	3/6/2002	234	26
11/19/2002	296	5	4/10/2002	128	28
1/7/2003	967	5	5/7/2002	2030	395
3/10/2003	626	5	6/11/2002	98	26
5/20/2003	831	5	7/16/2002	94	111
7/8/2003	227	5	9/5/2002	17	23
9/4/2003	590	5	11/12/2002	18	5
11/19/2003	12700	61	1/13/2003	27	5
1/20/2004	1250	14	2/3/2003	33	5
3/16/2004	642	5	3/10/2003	38	5
5/4/2004	1850	14	4/9/2003	302	39
7/7/2004	152	5	5/27/2003	82	36
9/7/2004	125	5	6/16/2003	113	64
11/23/2004	767	5	7/15/2003	16	12
1/25/2005	614	5	9/3/2003	1040	106
3/15/2005	293	5	11/24/2003	163	16
5/17/2005	266	5	1/14/2004	187	15
7/19/2005	129	5	2/2/2004	196	11
9/6/2005	81	5	3/9/2004	782	90
11/2/2005	118	5	4/19/2004	98	17
1/3/2006	219	5	5/20/2004	6490	548
3/6/2006	305	5	6/15/2004	877	166
5/8/2006	448	5	7/6/2004	755	460
7/10/2006	92	5	9/20/2004	357	29
9/12/2006	19	5	11/30/2004	1260	123
11/14/2006	370	5	1/24/2005	401	27
1/24/2007	1210	5	2/15/2005	5370	182
2/13/2007	7540	91	3/8/2005	1130	135
3/6/2007	511	5	4/4/2005	112	26
4/3/2007	676	13	5/2/2005	164	29
5/1/2007	439	5	6/22/2005	78	56
6/11/2007	80	5	7/12/2005	32	36
7/16/2007	32	5	9/7/2005	51	15

St. Francis River (07036100)			Lamine River (06907300)		
Date	Discharge (cfs)	NFR (mg/L)	Date	Discharge (cfs)	NFR (mg/L)
9/4/2007	15	5	11/2/2005	207	20
11/26/2007	57	5	1/3/2006	44	5
1/14/2008	452	5	2/6/2006	62	5
3/12/2008	955	5	3/7/2006	38	12
5/7/2008	401	5	4/10/2006	95	30
7/7/2008	60	5	5/4/2006	299	58
9/8/2008	127	5	6/14/2006	89	62
10/7/2008	51	8	7/6/2006	21	27
1/13/2009	120	8	9/6/2006	12	50
3/3/2009	373	8	11/6/2006	26	16
4/27/2009	13300	77	1/4/2007	245	78
			2/14/2007	3330	183
			3/7/2007	252	60
			4/3/2007	482	80
			5/3/2007	4820	460
			6/6/2007	105	106
			7/10/2007	171	42
			9/11/2007	18	30
			11/6/2007	28	31
			1/9/2008	3300	310
			3/6/2008	957	152
			5/6/2008	485	28
			7/9/2008	516	69
			9/2/2008	62	22
			10/21/2008	109	7
			1/12/2009	106	7
			3/9/2009	98	32
			5/5/2009	1220	110

Cedar Creek nr Columbia (0691041)			Bourbeuse River (07016400)		
Date	Discharge (cfs)	NFR (mg/L)	Date	Discharge (cfs)	NFR (mg/L)
10/11/1989	0.47	8	11/9/1992	65	2
11/9/1989	1.1	16	1/19/1993	575	1
12/5/1989	0.36	22	3/15/1993	397	4
1/19/1990	2.1	34	5/19/1993	913	136
2/14/1990	2.4	15	7/6/1993	461	19
3/21/1990	14	14	9/30/1993	1870	36
4/11/1990	4.7	17	11/3/1993	225	14
5/9/1990	8.1	13	1/20/1994	163	6
6/5/1990	1.1	5	6/7/1994	185	26
7/11/1990	713	1860	8/2/1994	72	30
8/8/1990	1.6	46	11/3/1994	63	8

Cedar Creek nr Columbia (0691041)			Bourbeuse River (07016400)		
Date	Discharge (cfs)	NFR (mg/L)	Date	Discharge (cfs)	NFR (mg/L)
9/6/1990	0.23	8	1/4/1995	205	2
10/11/1990	13	61	6/14/1995	1170	48
11/13/1990	0.55	13	8/2/1995	152	8
12/11/1990	4.8	26	11/21/1995	84	1
1/9/1991	3.9	32	1/22/1996	558	81
2/5/1991	60	73	6/3/1996	162	14
3/11/1991	2.6	26	8/20/1996	61	6
4/2/1991	2.7	7	11/13/1996	684	23
5/15/1991	20	42	1/8/1997	165	1
6/13/1991	0.94	20	6/17/1997	1030	52
7/16/1991	0.08	10	8/6/1997	52	13
8/14/1991	0.01	13	11/14/1997	159	8
9/5/1991	0.06	34	5/18/1998	180	12
			11/18/1998	172	7
			5/20/1999	230	12
			11/24/1999	75	2
			5/24/2000	201	5
			11/29/2000	57	5
			5/17/2001	69	11
			11/15/2001	46	12
			1/16/2002	109	5
			3/13/2002	709	18
			5/16/2002	1920	53
			7/10/2002	103	26
			9/5/2002	47	5
			11/5/2002	248	5
			1/8/2003	428	5
			3/5/2003	925	27
			5/21/2003	445	17
			7/23/2003	171	5
			9/4/2003	238	11
			11/12/2003	199	5
			1/12/2004	530	11
			3/1/2004	369	14
			5/4/2004	1850	64
			7/19/2004	183	12
			9/22/2004	67	5
			11/3/2004	2050	110
			1/6/2005	17100	278
			3/10/2005	358	14
			5/3/2005	863	24
			7/25/2005	133	5
			9/7/2005	109	31
			11/9/2005	101	5

Cedar Creek nr Columbia (0691041)			Bourbeuse River (07016400)		
Date	Discharge (cfs)	NFR (mg/L)	Date	Discharge (cfs)	NFR (mg/L)
			1/9/2006	178	11
			3/6/2006	103	5
			5/16/2006	586	25
			7/26/2006	45	5
			9/5/2006	66	16
			11/7/2006	125	5
			1/8/2007	207	5
			2/12/2007	191	5
			3/12/2007	247	5
			4/12/2007	450	5
			5/21/2007	201	5
			6/4/2007	152	5
			7/9/2007	173	14
			9/5/2007	29	5
			11/6/2007	38	5
			1/24/2008	60	5
			3/25/2008	816	30
			5/22/2008	386	10
			7/22/2008	168	16
			9/4/2008	1620	94
			10/28/2008	89	7
			1/20/2009	165	7
			3/24/2009	128	7
			4/20/2009	5820	318
			6/1/2009	527	40

Appendix A.4

USGS gaging sites used for synthetic flow development

Gage	Period of Record
USGS 06910230 Hinkson Creek at Columbia, MO	10/01/1989 - 06/21/2009
USGS 05506100 Long Branch near Santa Fe, MO	12/11/1994 - 06/21/2009
USGS 06909500 Moniteau Creek near Fayette, MO	07/13/2002 - 06/21/2009
USGS 05506800 Elk Fork Salt River near Madison, MO	10/01/1989 - 06/21/2009

Appendix B

Development of Suspended Solids Targets Using Reference Load Duration Curves

Overview

This procedure is used when a lotic[9] system is placed on the 303(d) List for a pollutant and the designated use being addressed is aquatic life. In cases where pollutant data for the impaired stream is not available a reference approach is used. The target for pollutant loading is the 25th percentile calculated from all data available within the ecological drainage unit (EDU) in which the water body is located. Additionally, it is also unlikely that a flow record for the impaired stream is available. If this is the case, a synthetic flow record is needed. In order to develop a synthetic flow record calculate an average of the log discharge per square mile of USGS gaged rivers for which the drainage area is entirely contained within the EDU. From this synthetic record develop a flow duration from which to build a load duration curve for the pollutant within the EDU.

From this population of load durations follow the reference method used in setting nutrient targets in lakes and reservoirs. In this methodology the average concentration of either the 75th percentile of reference lakes or the 25th percentile of all lakes in the region is targeted in the TMDL. For most cases available pollutant data for reference streams is also not likely to be available. Therefore follow the alternative method and target the 25th percentile of load duration of the available data within the EDU as the TMDL load duration curve. During periods of low flow the actual pollutant concentration may be more important than load. To account for this during periods of low flow the load duration curve uses the 25th percentile of EDU concentration at flows where surface runoff is less than 1 percent of the stream flow. This result in an inflection point in the curve below which the TMDL is calculated using load calculated with this reference concentration.

Methodology

The first step in this procedure is to locate available pollutant data within the EDU of interest. These data along with the instantaneous flow measurement taken at the time of sample collection for the specific date are recorded to create the population from which to develop the load duration. Both the date and pollutant concentration are needed in order to match the measured data to the synthetic EDU flow record.

Secondly, collect average daily flow data for gages with a variety of drainage areas for a period of time to cover the pollutant record. From these flow records normalize the flow to a per square mile basis. Average the log transformations of the average daily discharge for each day in the period of record. For each gage record used to build this synthetic flow record calculate the Nash-Sutcliffe statistic to determine if the relationship is valid for each record. This relationship must be valid in order to use this methodology. This new synthetic record of flow per square

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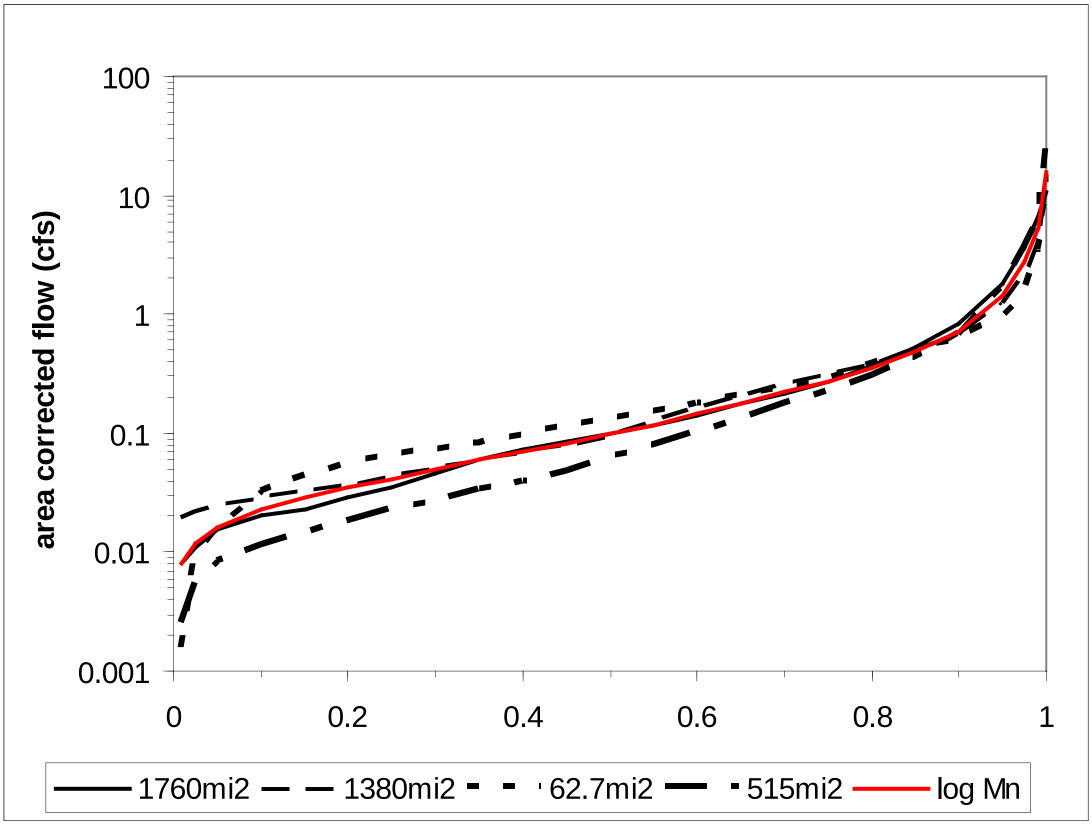
[9] Lotic = pertaining to moving water

mile is used to develop the load duration for the EDU. The flow record should be of sufficient length to be able to calculate percentiles of flow.

The following examples show the application of the approach to one Missouri EDU.

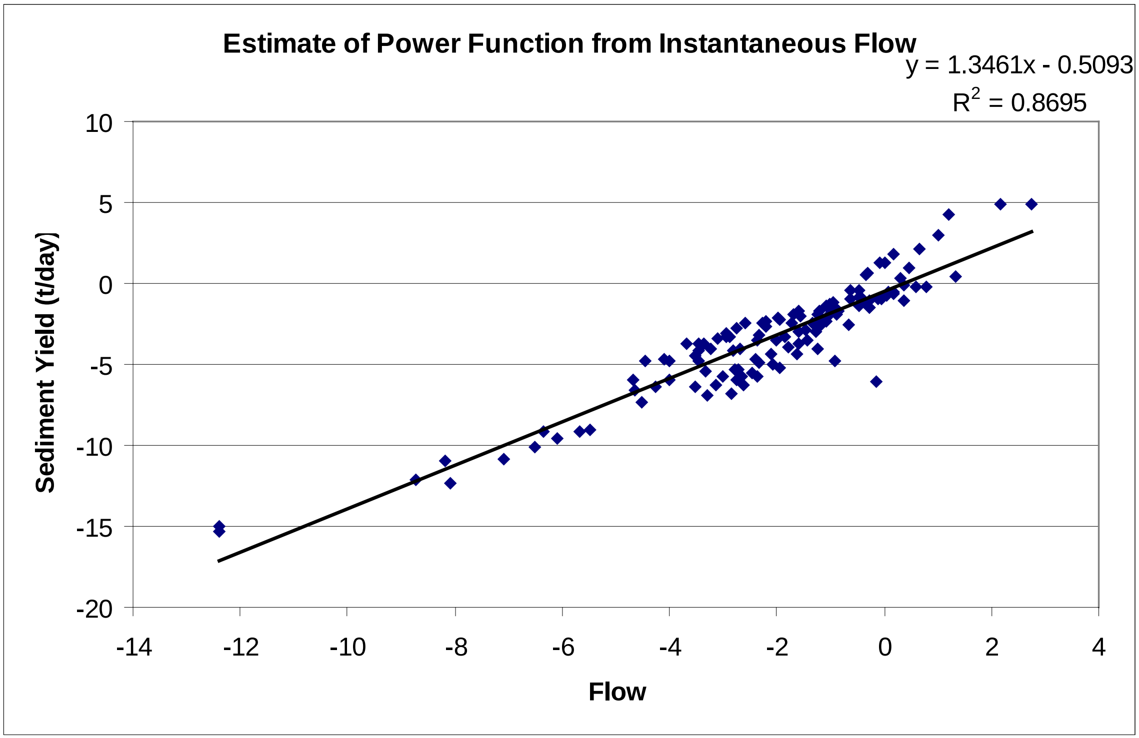
The watershed-size normalized data for the individual gages in the EDU were calculated and compared to a pooled data set including all of the gages. The results of this analysis are displayed in the following figure and table:



Gage	gage	area (mi^2)	normal Nash-Sutcliffe	lognormal Nash-Sutcliffe
Platte River	06820500	1760	80%	99%
Nodaway River	06817700	1380	90%	96%
Squaw Creek	06815575	62.7	86%	95%
102 River	06819500	515	99%	96%

This demonstrates the pooled data set can confidently be used as a surrogate for the EDU analyses.

The next step is to calculate pollutant-discharge relationships for the EDU, these are log transformed data for the yield (tons/mi^2/day) and the instantaneous flow (cfs/mi^2.) The following graph shows the EDU relationship:



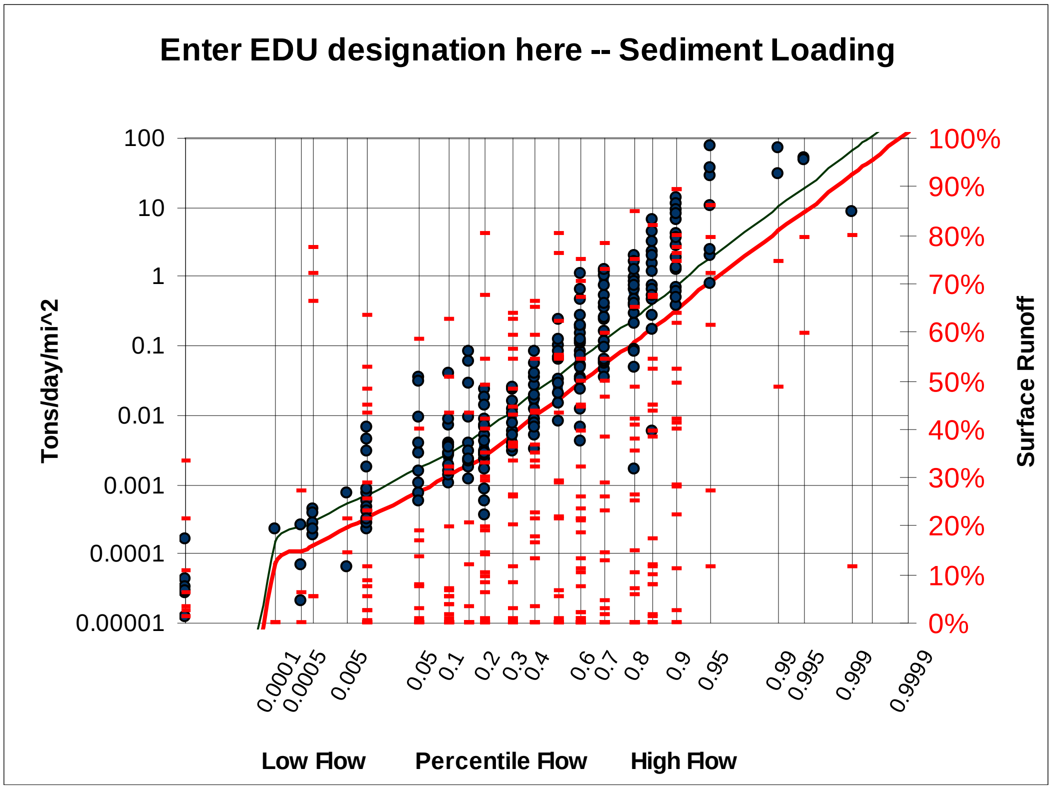
Further statistical analyses on this relationship are included in the following Table:

m	1.34608498	b	-0.509320019
Standard Error (m)	0.04721684	Standard Error (b)	0.152201589
r^2	0.86948229	Standard Error (y)	1.269553159
F	812.739077	DF	122
SSreg	1309.94458	SSres	196.6353573

The standard error of y was used to estimate the 25 percentile level for the TMDL line. This was done by adjusting the intercept (b) by subtracting the product of the one-sided Z_{75} statistic times the standard error of (y). The resulting TMDL Equation is the following:

*Sediment yield (t/day/mi^2) = exp (1.34608498 * ln (flow) - 1.36627)*

A resulting pooled TMDL of all data in the watershed is shown in the following graph:



To apply this process to a specific watershed would entail using the individual watershed data compared to the above TMDL curve that has been multiplied by the watershed area. Data from the impaired segment is then plotted as a load (tons/day) for the y-axis and as the percentile of flow for the EDU on the day the sample was taken for the x-axis.

Appendix C
Stinson Creek QUAL2K Modeling

I. Modeling Approach

1.1 Hydraulics/Hydrology

a. Hydraulic geometry relations were developed from the May 2008 flow measurements. Relationships between mean flow depth, width and velocity as a function of discharge were estimated from the water level measurements at the upstream and downstream sections (3.3 and 2.2 mi., respectively) from Fulton Wastewater Treatment Plant. These relationships were used in the QUAL2K calibration model.

b. The hydraulics/hydrology of the system was modeled assuming a water balance at the time of the sampling on May 20, 2008. The water balance was calculated using the measured upstream (ST-1), downstream (ST-6) and observed wastewater treatment plant discharge (at ST-3). Lateral inflows from contributing areas were estimated based on the water balance, i.e., nonpoint source flows were determined from the difference of the inflows and outflows of the modeled reach.

c. Smith Branch, a major tributary of Stinson Creek, was modeled as a point source flow instead of a diffuse flow (Tetra-Tech model assumes a diffuse flow). Nonpoint source flows from the remainder of the watershed contributing areas were treated as uniform lateral inflows into the modeled reaches, proportioned according to the percentage of the contributing area to the total watershed area.

1.2 Water Quality

a. Using the calibrated hydraulics model, the water quality (WQ) model was setup, parameterized and calibrated using the water chemistry data from May 20, 2008 sampling. The WQ model was calibrated by matching the observed diurnal dissolved oxygen data at sampling station 4 which is 0.1 mile downstream of the wastewater treatment plant discharge.

b. Kinetic rates were adjusted such that the predicted water chemistry parameters were reasonably simulated. Greater emphasis was placed on matching the biochemical oxygen demand decay downstream of the wastewater treatment plant discharge.

c. Since the weather condition of the May sampling was not generally representative of critical conditions, the calibrated model was modified using a representative hot and clear day in August, 2008. The weather data on August 6, 2008 from the Columbia Regional Airport station was used in the modified model. The critical condition model was run using the design discharge of Fulton Wastewater Treatment Plant at 4.54 cfs.

d. The critical condition model described above was used in various scenario runs to establish the wasteload allocation. Simulations were performed to determine the reduction in nutrients and biochemical oxygen demand necessary to meet the dissolved oxygen standard (5.0 mg/l) downstream of the plant discharge. The scenarios were:

d.1. **Model A** - Critical condition, design discharge, calibrated biochemical oxygen demand load (7 mg/l, calibrated concentration)

d.2. **Model B** - Critical condition, design discharge, permitted biochemical oxygen demand limits (45 mg/l)

d.3. **Model C**- Critical condition, design discharge, EDU reference Chlorophyll-A of 8 ppb (wastewater treatment plant discharge), calibrated biochemical oxygen demand (7 mg/l)

d.4. **Model D**- Critical condition, design discharge, EDU reference Chlorophyll-A of 8 ppb (wastewater treatment plant discharge), biochemical oxygen demand limits to meet standard (9 mg/l)

d.5. **Model E**-Critical condition, design discharge, EDU reference Chlorophyll-A of 8 ppb (wastewater treatment plant discharge), biochemical oxygen demand limits to meet standard (9 mg/l), nonpoint source EDU reference chlorophyll, total phosphorus and total nitrogen.

II. Model Results

2.1 Hydraulics/Hydrology

a. Figure C-1 shows the hydraulic geometry functions for the flow measurements on May 20, 2008.

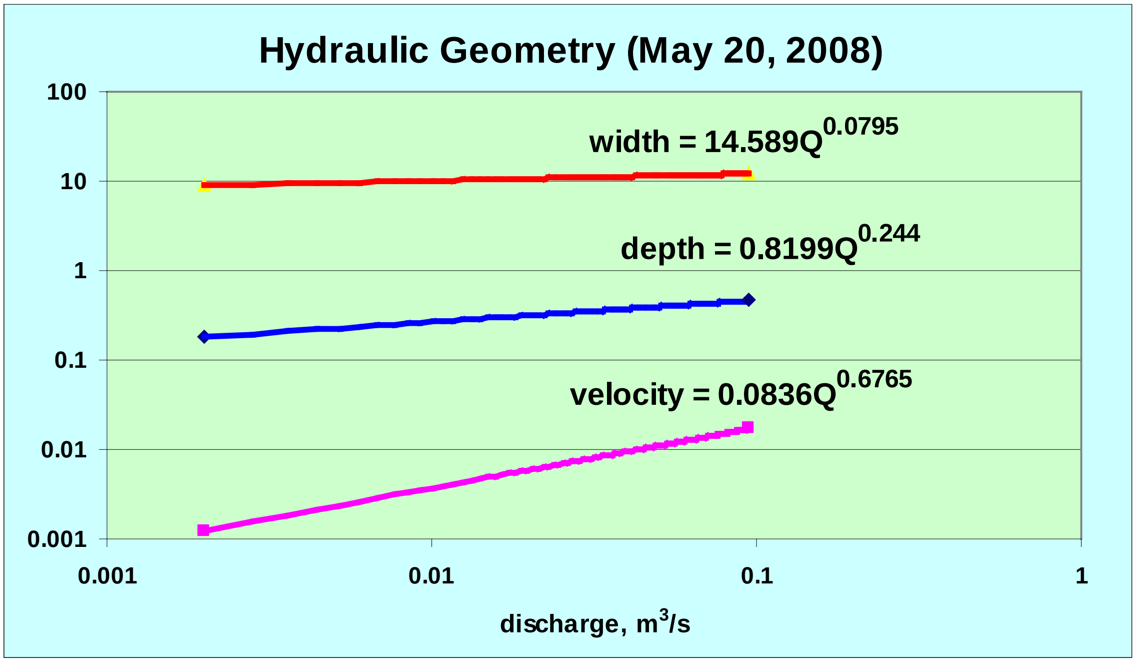
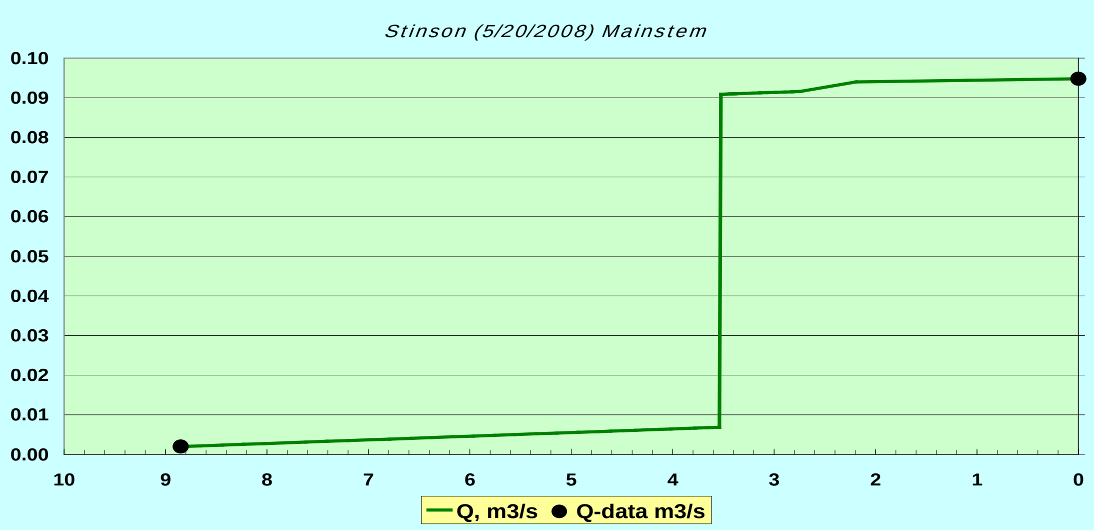


Figure C-1.Hydraulic geometry functions for Stinson Creek.

b. Figure C-2 shows the results of the flow, depth and velocity calibration using the measured data on May 20, 2008. The large increase in flow at about 3.54 km is due to the wastewater treatment plant discharge of 0.084 cms.



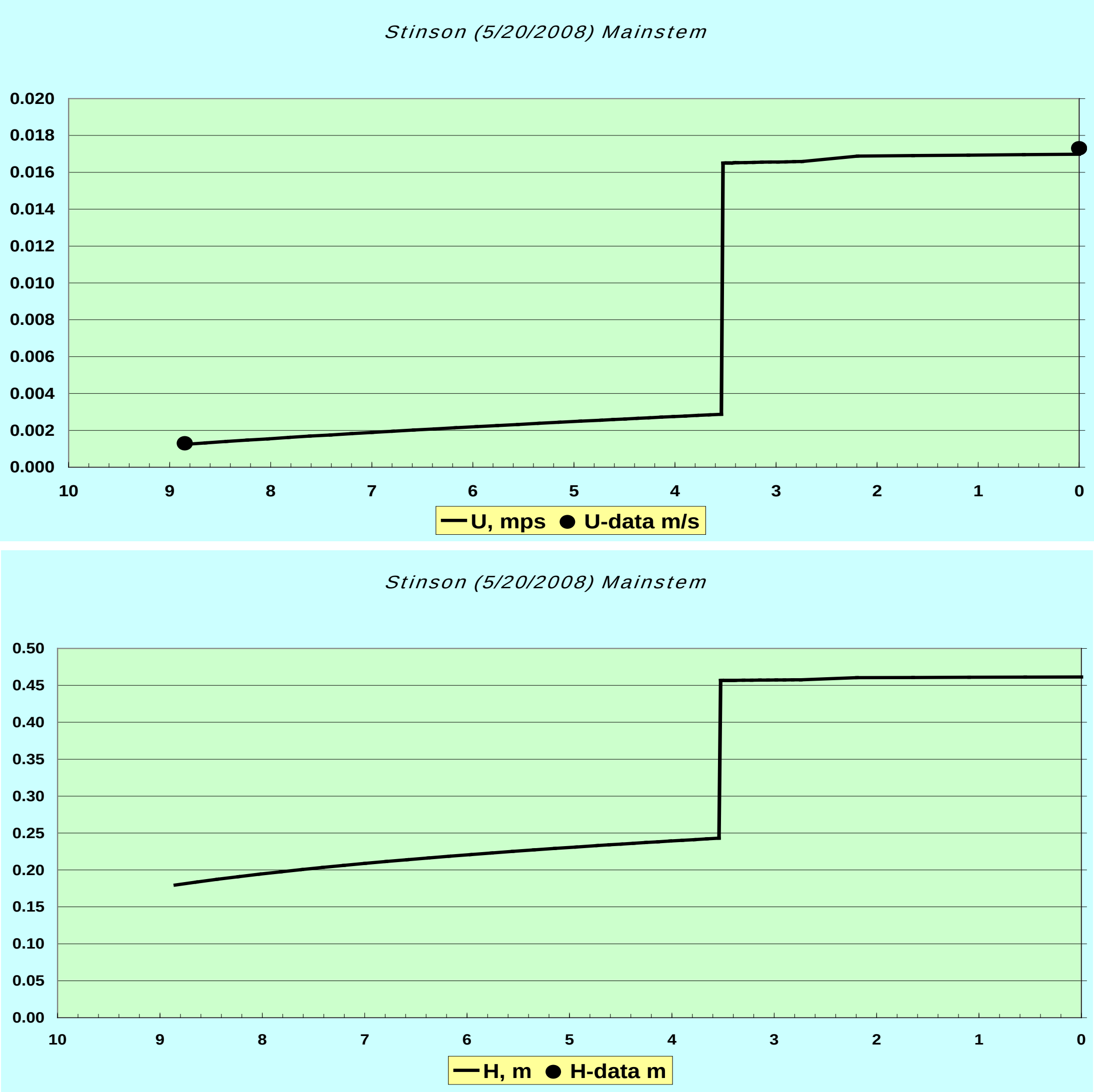


Figure C-2. Observed and simulated flow (Q), velocity (U) and depth (H).

2.2 Water Quality

a. The comparison of observed and predicted diurnal dissolved oxygen at ST-4 (0.1 mile downstream of the Fulton Wastewater Treatment Plant) is shown in Figure C-3. The model adequately predicts the diurnal variation in dissolved oxygen.

b. The predicted longitudinal profile of dissolved oxygen downstream of the Fulton Wastewater Treatment Plant is shown in Figure C-4. Also plotted in the graph are minimum, maximum and mean dissolved oxygen observed at ST-4.

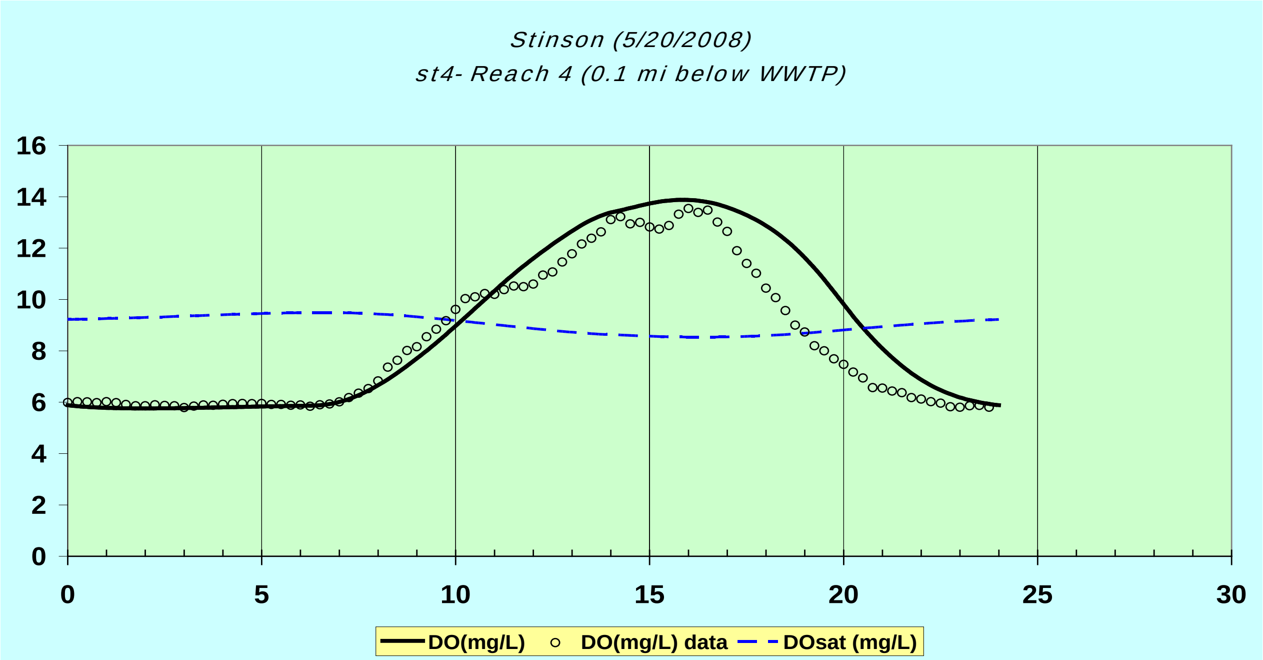


Figure C-3. Observed and predicted diurnal DO at ST-4.

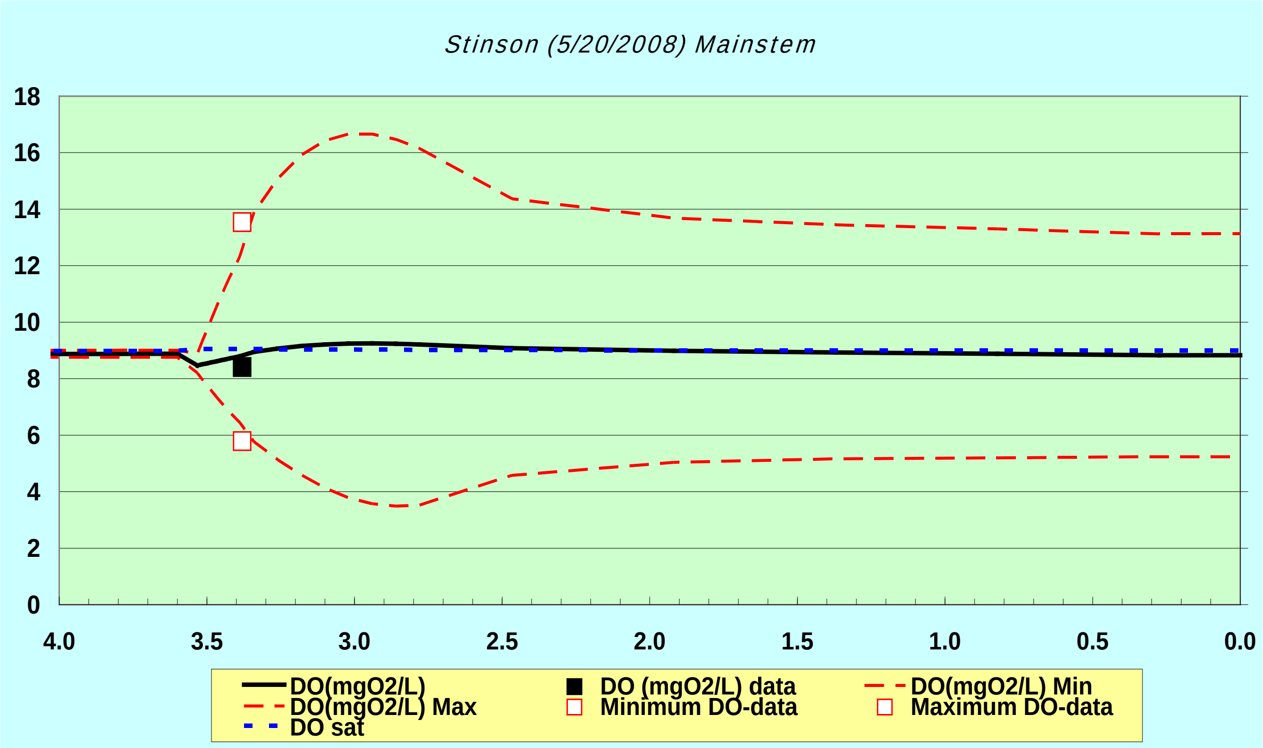


Figure C-4. Predicted longitudinal profile of min, max and mean dissolved oxygen downstream of wastewater treatment plant.

c. Figure C-5 shows the predicted longitudinal profile of minimum dissolved oxygen downstream of the Fulton Wastewater Treatment Plant corresponding to the various scenarios described in Section 1.2.d. As shown in the predicted profile from model D, under critical condition the dissolved oxygen criterion is met downstream of the wastewater treatment plant when the biochemical oxygen demand is limited to 9 mg/l and the EDU reference Chlorophyll-A is set at 8 ppb. There is insignificant difference between the profile for model D and E. From model B at the permitted biochemical oxygen demand limits, the minimum dissolved oxygen drops below 5 mg/l at about 0.1 mile downstream of the wastewater treatment plant.

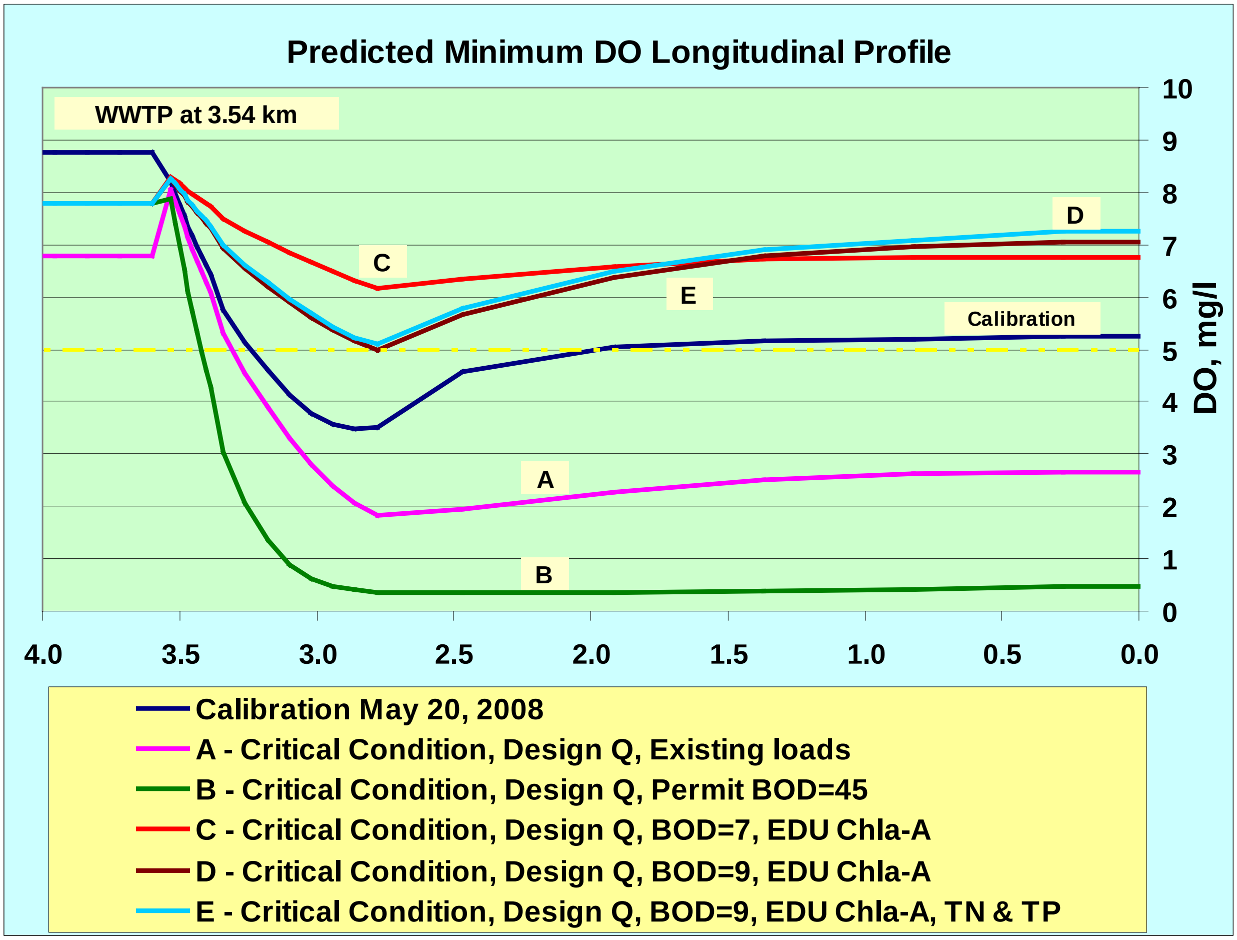


Figure C-5. Predicted longitudinal profile of minimum dissolved oxygen downstream of wastewater treatment plant corresponding to various simulation scenarios.

III. Wasteload Allocation

The wasteload allocation for the Fulton Wastewater Treatment Plant is calculated based on the results of model D/E and is summarized in Table C-1.

Table C-1. Wasteload Allocation for Stinson Creek

Fulton WWTP	**Concentration Limits,**	**WLA at Design Flow Q = 4.54 cfs**
BOD	9 mg/l	220 lbs/day
Chl *a*	8 µg/l	0.2 lbs/day